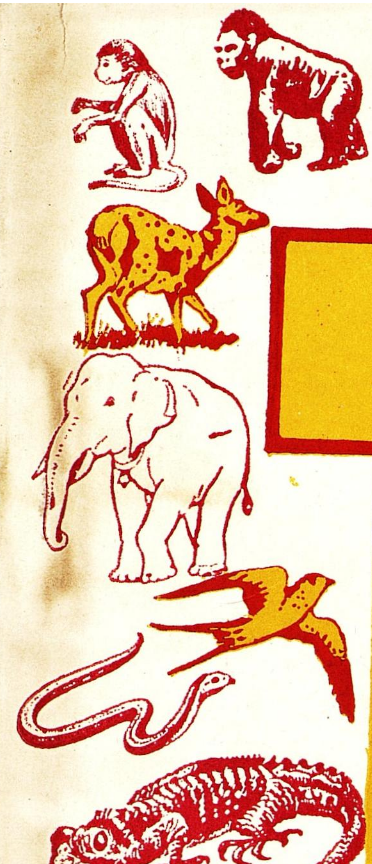

ZOOLOGY

HIGHER SECONDARY FIRST YEAR

Vol. I

TAMILNADU TEXTBOOK SOCIETY

ZOOLOGY

Vol. I

Higher Secondary – First Year

TAMILNADU TEXTBOOK SOCIETY
MADRAS

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CHAPTER I

An Introduction to the Science of Life

The immense variety of architecture which has been utilized in the structural designs of animals is one of the greatest fascinations to the professional Zoologist as well as to an ordinary man. Equally exciting are the chemical inter-actions by which the animals have solved their functional problems. Our knowledge in these respects has expanded greatly in recent times due to modern scientific methods employed in the study of Biology.

The fields of Biology

A great many sciences are included under the term Biology. It is generally recognised that two great groups of living things exist - viz. Plants & Animals. The study of plants is called Botany (Gr. botane, plant) and the study of animals is called Zoology (Gr. Zoon, animal + logos, discourse). Within these divisions there are sub-divisions of biology relating to the study of particular groups of animals and plants *e.g.* Ornithology (study of birds), Bacteriology (study of bacteria) etc.

From entirely different points of view, the fields of Biology may be classified into Morphology, concerned with structure, Physiology (Gr. Phuris, function) having to do with function; Anatomy (Gr. anatomia, to cut up) which is the study of structure as determined by dissection; Histology (Gr. histos, tissue), the study of tissues (microscopic anatomy); Taxonomy (Gr. taxon, arrangement), the study of classification of living organisms and Palaeontology (Gr. Palaios, ancient) the study of fossil organisms. Certain fields are both morphological and physiological; they are Cytology (Gr. cytos, cell), the study of cells; Embryology — the study of development; Genetics (gr. genesis, to be born), the study

of heredity; and Ecology (Gr. oikos, house)—the study of the relations of organisms to each other and their environments.

Though these branches of study are varied and specialised there are certain fundamental principles which unify the several fields of Biology.

Need to study Biology

Biology is a complex science with a number of problems yet to be solved. This alone is a sufficient challenge to an enquiring and intelligent mind. Further (1) man is the product of the biological heritage of the past and he is a product of the evolutionary process. Since there is an underlying unity of structure and function throughout the animal kingdom, much information can be obtained by studying other animals. (2) Biology is of practical importance because of our dependence upon animals for many products such as food, clothing, drugs, etc. (3) A study of Biology is necessary for preprofessional work in medicine, agriculture, dentistry, veterinary, sanitary engineering, conservation etc. (4) It forms a basis for psychological and sociological studies. (5) Animals influence man's welfare in harmful ways and a knowledge of their habits enables us to eradicate them.

Regardless of these values, the field of Biology can lead the student to appreciate all beauty, whether in nature or in art, and to respect others as himself, which, according to Thomas Huxley, defines an educated man.

This is Life: The characteristics of living matter

In addition to the approaches to the study of Biology already mentioned, there are other approaches of study, viz. (1) a descriptive approach, based largely on observations and (2) an experimental approach. This latter approach has become greatly advanced in the past 75 years. Investigations in the biological sciences are not easy, however, for the biological units show a great variety. Two healthy individuals of the same age, size and environment may react very differently to some experimental factor. For instance, a drug may be highly effective in one individual; in another it may react in an entirely different manner. It is one of the reasons why biological investigation has not yet solved some diseases such as cancer.

When the experimental method gained a foothold, workers in biology were alert to new techniques whenever they saw them. Thus, x-rays and tracer techniques were put to use in Biology experiments. Much importance was also given to Mathematics to express the life process. Many concepts and principles of Physics and Chemistry were used in the experimental pursuits of Biology.

Protoplasm as material basis of Life

Any living thing, plant or animal, regardless of its size or complexity of organization may be called an organism. Living matter was first called **protoplasm** by Punkinje (Gr. protos = first, plasm = anything formed) in 1840 and **sarcode** by Dujardin in 1835. It is often stated that organisms are composed of protoplasm but it must be emphasised that it occurs only as organized individuals and it cannot be considered apart from the organism. It was first thought that protoplasm was a definite chemical substance; but investigation has shown that it is not a single chemical substance but is made up of different compounds and that it differs in every species of plant and animal life and probably in every kind of cell. Owing to the uniformity of the life processes within all animals and plants, we speak of the properties of protoplasm as though it were one single kind of substance. Fortunately, many of the modern techniques enable us to study the organism or parts of an organism while vital activities are proceeding. The application of these techniques has led us to organize our information concerning the properties of protoplasm into three categories: the biological, the physical and the chemical. All the three categories are inter-related.

A. Biological properties

Living matter exhibits the phenomena of growth, reproduction, movement and irritability. It has become increasingly evident in recent years that no sharp line of demarcation can be drawn between living and nonliving systems. The implications of this statement can be understood better if the above four features are considered in detail.

1. Growth and metabolism

Growth is the most complex of all vital processes. By growth, organism increases in volume by forming new

protoplasm and what is more, the new protoplasm is synthesized from simple chemical compounds. Further, the protoplasm is peculiar to the organism which synthesizes it and is the structural basis of the organism, providing energy for all activities. The *Metabolism* is the term used to include these complex chemical changes. Those processes which use energy to build up compounds are said to be anabolic; those by which substances are broken down, thereby releasing energy, are termed catabolic.

Animals are unable to make organic compounds from simple inorganic substances; in this respect they differ from plants, which manufacture sugar (glucose) from carbon-dioxide (CO_2) from the air, water (H_2O) from the soil, and energy from light. Chlorophyll in the plants is also necessary. The reaction for the formation of glucose from carbon-dioxide and water is better understood and can be illustrated by the following simple equation:

$$6CO_2 + H_2O + \text{energy} + \text{catalyst} \longrightarrow C_6H_{12}O_6 + 6O_2 \uparrow$$

This reaction is aptly named photosynthesis and is one of the most important manufacturing processes on earth, because energy from the sun is 'stored' in glucose for later use by the organisms. Glucose once formed, forms the key stone for the formation of other complex compounds such as carbohydrates and fats or lipids; and by the addition of nitrogen, the amino acids and proteins.

Since animals must have organic food, plant products are necessary either directly or in the form of protoplasm built up by other animals out of plant food. Before animal growth is possible, food must be converted into living substance. This is done by digestion and assimilation, which is an important anabolic process. Energy that is contained in the organic molecules in protoplasm and in stored substances in the body is liberated when these molecules are broken down in oxidation. A single example of the oxidative process is as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Oxidation, therefore is a breaking down of protoplasm and is a catabolic process.

It is thus evident that protoplasm is a remarkable chemical laboratory. Some insight has been gained with regard to the

way in which the protoplasm performs its chemistry. The key lies in the presence of special proteins, the enzymes which control the rate of the chemical reactions and act as the organic catalysts. To understand life processes fully, our knowledge of the enzymes and what they do within the protoplasm must be explored.

Equally important in growth is the increase in the amount of water and salts. In other words, as the amounts of carbohydrates, lipids and proteins are increased, the amount of water must also increase, or the protoplasm would become progressively more concentrated.

2. Reproduction

If the plants and animals are to be successful they must not only form new protoplasm but must also create new individuals. It is therefore imperative that organisms reproduce if they are to survive.

There are two processes involved in reproduction.

(a) Replacement of worn out or damaged parts - regeneration.

(b) Creation of new individuals.

These two processes and the mechanisms by which they are brought about are among the most fascinating problems of modern biology.

3. Movement

Movement is one of the most vivid characteristics of living matter. Protoplasm is never stationary and there is corresponding expenditure of energy. A seed or a hibernating animal may appear to be without visible movement but careful examination will show that there is slow movement of the protoplasm, slight movement of the blood etc.

4. Irritability

Awareness of its surroundings and ability to make responses to a variety of stimuli are fundamental characteristics of living systems. It involves the ability to distinguish to some extent between the stimuli which reach the protoplasm, and often is

associated with special receptors. Mere awareness is not sufficient; the organism must respond. Responses may be positive or negative; and the response may occur immediately or be delayed for a longer period. Continued stimuli may result in the organism producing structural adaptations.

B. Chemical Properties

The chemical elements found in living matter are not unique to the protoplasm. It is the relative proportion of the compounds in protoplasm that is significant. Nearly 95% of the protoplasm is formed of six elements, viz. oxygen, hydrogen, carbon, nitrogen, calcium, and phosphorus and the remaining elements constitute the 5%. Of these six elements, carbon is specially important, because of two special properties. It has four valence bonds, which allow it to attach at four places with the atoms of other elements and secondly, the carbon atoms have the property of combining with themselves.

C. Physical Properties

It is not possible to separate completely the properties of protoplasm into physical and chemical properties. But it has been done so here only for convenience and better understanding.

Protoplasm has a higher water content and is therefore a fluid. It varies however in its consistency. It becomes very gelatinous at times (gel) and can change very rapidly to watery condition (sol). This characteristic has advantages, in that the protoplasm can utilize the advantages which accompany the fluid movement and also can retain the stability of the gel or semi-solid state.

Many minute granules can be seen in the protoplasm with the aid of the microscope. When the protoplasm is in a liquid state or in the sol state, the granules can be seen moving about. This is known as the Brownian movement, having been discovered by an English Botanist, Robert Brown in 1827. This type of movement is also seen in water and other liquids and is not necessarily a sign of life.

Protoplasm is a **colloid**, a physical condition in which relatively large particles, such as clumps of molecules and very

large molecules are suspended in fluid. The particles in the protoplasm have a great affinity for water and chemical reactions occur on their surface. Since the number of surfaces presented by the colloidal particles are exceedingly numerous, and since the surface area presented by the particles are enormous, countless number of chemical reactions can go on simultaneously in the protoplasm.

Other important features of the physical phase of the protoplasm are the direct results of the high water content. Water is an almost universal solvent and many diverse chemical substances dissolve in water and thus can be incorporated into the protoplasm. Insoluble substances like oils, form **emulsions** with water in the protoplasm. Secondly, water has a high specific heat which means that it changes temperature slowly. This factor provides a safety factor to the organisms when their surroundings become suddenly hotter or cooler. Thirdly, water changes its physical state within a very narrow temperature range. At 0° C (32° F) water is a **solid,** ice; between 0° C and 100° C (212° F) it is a **liquid;** above 100° C water becomes a **vapour,** steam. These facts limit the protoplasm's existence; it can survive freezing under special conditions for a very short time but is coagulated and destroyed at high temperature. Organisms are less adaptable to higher than to lower temperatures, probably because the enzymes are destroyed quickly by heating and the membranes become more permeable.

Living and non-living matter

The above characteristics were once thought to be peculiar to protoplasm. Modern techniques show that many models can duplicate them. In fact, such problems like permeability of the membrane, transmission of impulses along nerve fibres, nature of movement of materials into and out of the protoplasm, etc., have been studied through models.

The study of **viruses** have also demonstrated that there can be no absolute distinction between living and non-living matter. They undoubtedly provide a connecting link between ordinary molecules and protoplasm. Viruses can therefore solve many biological problems and are extremely helpful in their analysis experimentation.

CHAPTER II

Biology

Biology is the study of all living organisms. The living organisms are of so many different types that it is difficult for any one to study all the types in detail. To help one to have a fair knowledge of the ways of life of the living organisms, classification of the organisms based on similarities and differences has been devised.

Living organisms include both plants and animals. These two can be distinguished by looking at the different characteristic ways of the organisms. Points that help us differentiate plants and animals are (1) method of nutrition; (2) Nature of growth; (3) Form and symmetry; (4) Locomotion and (5) details of the cell structure. However, we should not lose sight of the fact that there are regions where this clear difference is not possible. The study of the plants constitutes **Botany** and the study of animals **Zoology**. There are many branches of both the disciplines.

Animals live in different habitats. They are of different sizes ranging from a microscopic size to huge forms like the whale. The animals have been classified into various levels of organisation in structure, form, and ways of life. The study of classification is known as **Taxonomy.**

The living world is divided into two kingdoms namely (1) the **plant kingdom** and (2) the **animal kingdom** or kingdom **Animalia.** The animal kingdom is broadly divided into sub kingdoms namely (1) **subkingdom Invertebrata** comprising of animals without backbone and (2) **subkingdom Chordata.** This division is based mainly on the fact that Invertebrate animals do not have a dorsal median supporting rod or notochord as it is called, while the chordates have them. Besides this, there are other points of differences also. The chordates have paired

pharyngeal gill clefts, a post anal tail, a ventral heart, a hepatic portal system, and a dorsal tubular nerve cord. Besides, no chordate has more than two pairs of limbs. The respiratory pigment is in the blood corpuscles. The common cockroach is an example of the invertebrata and the frog, and we too, are examples of chordata.

Each subkingdom is further divided into many big groups called **phyla**, based on radically different plans of organisation. A phylum is a big group having in it, all animals, with the same basic plan of organisation of their bodies.

Each phylum, is split up, for convenience into different **classes**, on the basis of very significant variations, in the plan of organisation. The classes are further broken up into **orders**, on the basis of clearly observable differences. Each order consists of many **Families**, and each family is made of several **genera**. Every genus may have, many different **species**. The species forms, the ultimate level or basic level. The species is defined as a group of animals which will normally interbreed in a natural population and which maintain the same chro mosomal set up.

Thus we find a gradation in classification:

Kingdom
Sub kingdom
Phylum
Class
Order
Family
Genus
Species

Every animal can be fitted in this scheme of gradation. For example, the brown cockroach, is called scientifically, as **Periplaneta americana.** The first half of the name, Periplaneta is the name of the genus, **americana** is the name of the species. All organisms, both animals and plants, are named like this, by two names, one a generic name and the other, a specific name. Usually the generic name is written with a capital letter, and the specific name with a small letter. The same genus, may have another species such as **Periplaneta orientalis,** the yellow and black cockroach.

As our knowledge expands, further divisions of these grades, lik subphylum, subclass, suborder, subfamily etc. are introduced.

This method of naming every organism by two names is called **Binomial nomenclature.**

This was first invented by Carl Linnaeus (1707-1778) a Swedish naturalist.

How the cockroach fits in the scheme of classification is shown below.

Kingdom	—	Animalia
Subkingdom	—	Invertebrata
Phylum	—	Arthropoda
Class	—	Insecta
Order	—	Orthoptera
Family	—	Blattidae
Genus	—	**Periplaneta**
Species	—	**americana**

Similarly the green pond frog is placed in classification as below:

Kingdom	—	Animalia
Subkingdom	—	Chordata
Phylum	—	Chordata
Subphylum	—	Craniata or Vertebrata
Class	—	Amphibia
Order	—	Anura
Family	—	Ranidae
Genus	—	**Rana**
Species	—	**hexadactyla**

The important phyla of the animal kingdom are given below:

1. Phylum Protozoa (e.g.) Amoeba, Euglena, Paramoecium, Plasmodium
2. Phylum Porifera (e.g.) Sponges
3. Phylum Cnidaria or (Coelenterata) (e.g.) Hydra, Jellyfishes

4. Phylum Platyhelminthes (Flat worms) (e.g.) Planarians, Tapeworm, Liver fluke

5. Phylum Aschelminthes (Nemathelminthes) (Round worms) (e.g.) Ascaris

6. Phylum Annelida (e.g.) Earthworm, Nereis, Leech

7. Phylum Arthropoda (e.g.) Crab, Prawn, Centipede, Millipede, Insects, Scorpion, Spider

8. Phylum Mollusca (e.g.) Clams, Snails, Slugs, Octopus

9. Phylum Echinodermata (e.g.) Star fishes

10. Phylum Chordata is divided into two groups namely Acrania or Prochordates and Craniata or Vertebrates

Prochordates	(e.g.) Amphioxus
Craniata	(e.g.) Shark, Bony fishes Frog, Snakes, Turtles, Lizards, Crocodiles, Birds, Mammals.

1. Phylum Protozoa: The animals belonging to this phylum have the following general characters.

1. The animals are very small and microscopic.
2. The animals are made of single cells. So these are called unicellular organisms.
3. There is no symmetry.
4. Various activities of life are carried on by parts of the cell called organelles.
5. The animals reproduce by fission and in some cases by conjugation and by sexual methods.
6. There is no natural death as the mother's body is divided among the offsprings.

This phylum is divided into five classes namely

(1) Rhizopoda or Sarcodina
(2) Mastigophora or Flagellata
(3) Ciliata or Ciliophora
(4) Sporozoa and (5) Suctoria.

Class (1): Rhizopoda (e.g.) Amoeba.

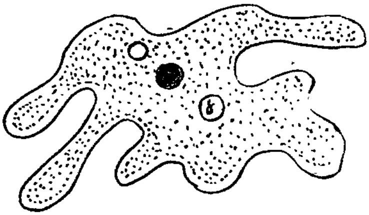

Fig. 1
Amoeba

Animals have blunt temporary projections called pseudopodia. There is no definite shape of the body. Locomotion is by the pseudopodia.

Class (2): Mastigophora (e.g.) Euglena

Animals have a definite shape. The locomotor organ is the long whip like flagellum or mastix. Many forms have chloroplasts.

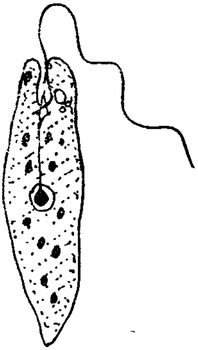

Fig. 2
Euglena

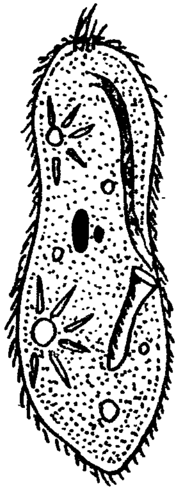

Fig. 3
Paramoecium

Class (3): Ciliata (e.g.) Paramoecium

Animals are provided with vibratile hair like cilia which help locomotion. Some have two nuclei. A method of reproduction called conjugation is common.

Class (4): Sporozoa (e.g.) Plasmodium

Many of these are parasites requiring another host to live upon. No special locomotor organs are present. Reproduction is both by asexual and sexual methods. Some require two hosts to complete the life history.

Fig. 4
Plasmodium

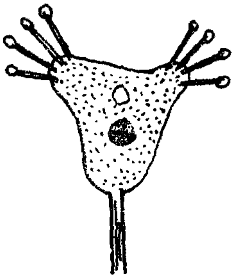

Fig. 5
Acineta

Class (5): Suctoria (e.g.) Acineta

Animals are sedantary. They have tentacle like suckers with the help of which they feed.

2. **Phylum Porifera:** The animals in this phylum are characterised by

1. Except a few, all animals are marine, and sedantary.
2. Animals are multicellular, but there is no true tissue formation.
3. Animals have a detailed canal system through which sea-water is made to flow.
4. Special collered cells with flagella called Choanocytes are seen on the inner walls.
5. Body is reinforced by Calcareous spicules of different patterns.
6. No part of the body is dependant on other parts and so power of regeneration is great.
7. Both sexual and asexual reproduction are present.

This phylum is divided into three classes namely
(1) Calcarea (e.g.) Leucosolenia (2) Hexactinellida e.g.) Hyalonema and (3) Demospongiae (e.g.) Spongilla.

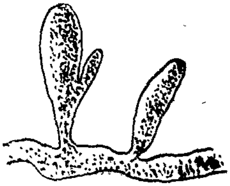

Fig. 6
Leucosolenia

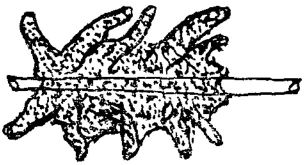

Fig. 8
Spongilla

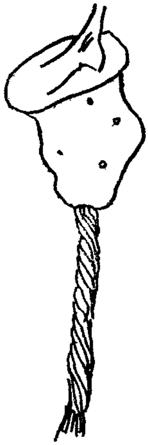

Fig. 7
Hyalonema

3. **Phylum Cnidaria** (Coelenterata): This phylum consists of animals with the following general characters.

1. All are multicellular animals showing a tissue grade of organisation.
2. Almost all are marine animals except the Hydra.
3. Animals exhibit radial symmetry.
4. Body wall is made of two layers of cells namely the ectoderm and the endoderm with a jelly like mesoglea in between. So the animals are said to be **diploblastic.**
5. **There is a coelenteron** or gastrovascular cavity which is both the body cavity or coelom and the alimentary cavity or enteron.
6. Stinging cells or Nematocysts are peculiar to this phylum. These help in feeding and in defence.
7. Some animals secrete a horny or calcareous skeleton which becomes the coral.
8. There is a loose network of nerve cells.
9. Some forms show polymorphism with division of labour among the branches.

10. The life history shows the phenomenon of alternation of generations.

The phylum is divided into three classes namely (1) Hydrozoa (2) Scyphozoa and (3) Anthozoa.

Class (1): Hydrozoa (e.g.) Hydra.

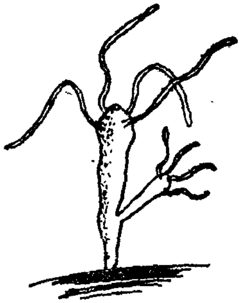

Fig. 9
Hydra

This is a fresh water coelenterate. Body is cylindrical. The base is attached to the substratum. The free end has the mouth, surrounded by a set of hollow tentacles. The body wall is made of two layers, an outer ectoderm and an inner endoderm. In between the two, there is a jelly called mesoglea. The tentacles are rich in special stinging cells called Nematocysts. There is only one cavity inside the animal, called coelenteron or gastrovascular cavity. The animal moves from place to place, by gliding, somersaulting or caterpillar like movements. It feeds on waterfleas. The digestion is partly extracellular and partly intracellular. There is no anus. There is a network of nerve cells throughout the body. The animal reproduces asexually by budding and also sexually by forming gametes.

Class (2): Scyphozoa (e.g.) Aurelia.

This is popularly called the jelly fish. This has an umbrella like part from which root like oral arms hang down. This marine form is the medusa stage. The polyp stage is shortlived. Stinging cells are in the oral arms. There is a well defined canal system in the medusa.

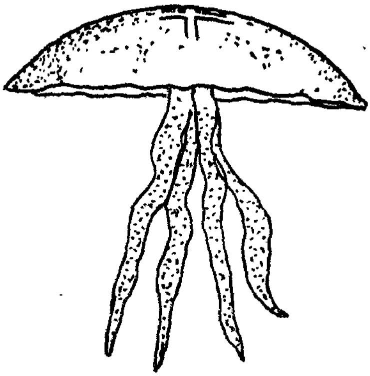

Fig. 10
Aurelia

Class (3): Anthozoa (e.g.) Sea anemones.

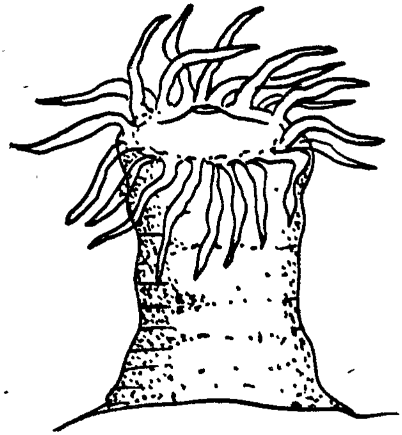

Fig. 11
Sea-anemone

These sedantary marine animals look like flowers. The body is cylindrical with a flat top in the centre of which is the mouth. Surrounding the mouth, there are numerous finger like tentacles. The cavity inside is separated into many chambers by mesenteries. Many anemones secrete a calcareous skeleton, which becomes the coral.

4. **Phylum Platyhelminthes** (Flat worms): The animals in this phylum are having the following general features.

1. The animals are dorso-ventrally flattened.
2. They show bilateral symmetry.
3. Animals have three main layers of cells namely ectoderm, endoderm and mesoderm. So these are said to be triploblastic animals.

   Animals reach an organ system level of organisation.

5. There is no coelom, as it is occupied by parenchyma cells.
6. Excretion is effected by peculiar cells called flame cells or solenocytes.
7. A primitive brain with two lateral nerve cords is seen.
8. Reproduction is by sexual method. Most of the animals are hermaphrodites.
9. Adaptation to parasitic existence is well developed in many forms.
10. Power of regeneration is marked.

This phylum is divided into three main classes namely 1. Turbellaria 2. Trematoda and 3. Cestoda.

Class 1: Turbellaria (e.g.) Planarians

These are small flat worms usually free living. Eyes are present. There is a definite antero posterior axis. Animal shows extraordinary regenerative powers.

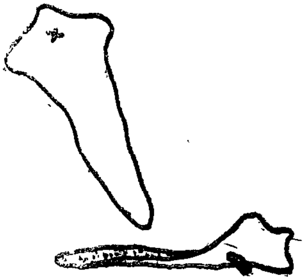

Fig. 12
Planarians

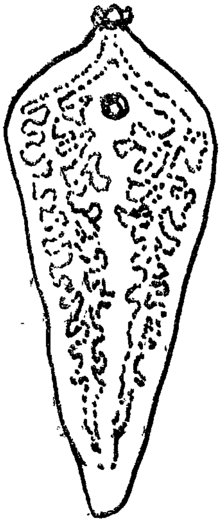

Fig. 13
Liver-fluke

Class 2: Trematoda (e.g.) Liver fluke

This is a parasite in the liver of sheep. Animals show extreme adaptation to parasitism. Loss of locomotor organs, sense organs and digestive glands, development of powerful attachment organs like suckers, and extraordinary reproductive systems, to produce large number of young ones are some examples of this adapation. This animal completes its life history in two hosts namely sheep and a pond snail. Paedogenesis (*i.e.*) larval multiplication is characteristic.

Class 3: Cestoda (e.g.) Tapeworm.

This is an intestinal parasite in man. It has a head like scolex with hooks and suckers for strong attachment. The body looks like a flat tape with numerous segments called proglottids. The body is covered by an enzyme resisting cuticle. Locomotor organs, sense organs and digestive organs are absent. Every segment has a complete male and female reproductive system. Excretion is by flame cells. Life history is completed in two hosts namely man and pig.

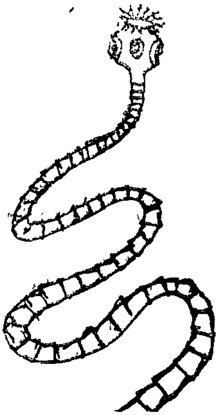

Fig. 14
Tapeworm

Phylum Aschelminthes or Nemathelminthes (Roundworms)

The animals in this phylum have the following general characters.

1. Animals are long, cylindrical and without any segmentation.
2. Animals show sexual dimorphism. The females are usually straight and the males are shorter and posteriorly curved.
3. The body wall has a cuticle and a syncytial epidermis.
4. A true coelom is absent, and hence it is called pseudocoelom.
5. Sexes are separate. A large number of eggs are produced.
6. Some are free living and many are parasitic.

Fig. 15
Ascaris lumbricoides

This phylum is having only one class by name Nematoda. (e.g.) Ascaris lumbricoides.

This is an intestinal parasite in man. Male and female look different. Female is longer and straight. Male is shorter with a curved posterior end. Infection is carried on by contamination through water, vegetables, and by the house fly.

Phylum Annelida This phylum has animals with the following general features.

1. Body is cylindrical and marked both externally and internally into numerous segments.
2. All segments have more or less identical arrangement of organs. This is called Metamerism.
3. Body wall has both circular and longitudinal muscles.
4. A true coelom is present.

5. There is a closed blood vascular system with coloured blood due to haemoglobin dissolved in the plasma.
6. Excretion is carried on by special paired tubes called nephridia.

This phylum is divided into three main classes namely 1. Archiannelida 2. Chaetopoda and 3. Hirudinea.

Class 1: Archiannelida (e.g.) Polygordius.

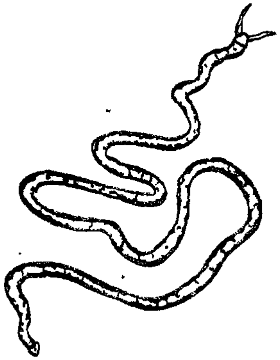

Fig. 16
Polygordius

This is a marine worm with clear internal segmentation but outwardly with faint markings only. There are no parapodia and no setae.

Class 2: Chaetopoda

This is divided into two groups namely Polychaeta and Oligochaeta. Nereis represents polychaeta and earthworm represents oligochaeta. Nereis is a marine worm with a distinct head with tentacles and eyes. The body is flat and metamerically segmented. Each segment has a pair of parapodia with numerous setae, which help in locomotion and respiration. There is a larval stage in life history. Earthworm is terrestrial, living in

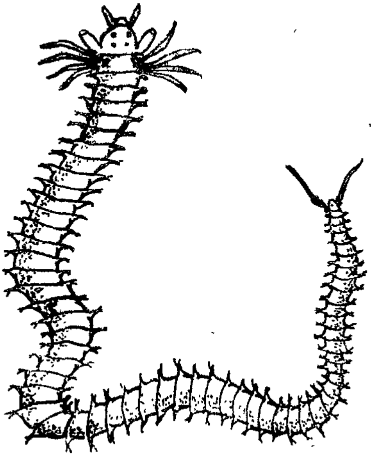

Fig. 17
Nereis

moist soil in burrows. Body is cylindrical and metamerically segmented. Parapodia are absent; numerous setae are embedded in the skin which help in locomotion. Eyes are absent. Movement is by circular and longitudinal muscles. Excretion is by paired tubes called nephridia. Animal is a hermaphrodite and sexual reproduction takes place. There is no larval stage.

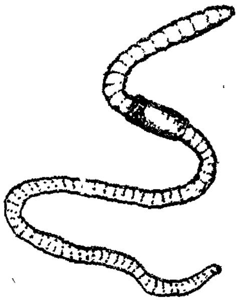

Fig. 18
Earthworm

Class 3: Hirudinea (e.g.) Leech.

Fig. 19
Leech

This is an occasional external parasite, living on the blood of vertebrate hosts. It is mainly aquatic. There is an anterior and a posterior sucker. Body is made of 33 segments. Setae are absent. Animal is hermaphrodite and there is no larval stage.

Phylum Arthropoda

This is a very big phylum including a large number of animals. The animals in this phylum have the following common features.

1. Body is metamerically segmented, and shows bilateral symmetry.
2. There is a distinct cephalisation.
3. The body is covered by hard chitinous plates forming an exoskeleton.
4. Most of the segments of the body bear paired appendages.
5. The appendages are many jointed and hence the name Arthropoda.
6. Body cavity is a haemocoel or blood-space.
7. Excretion is by Malpighian tubules or Green glands.
8. Eyes are compound eyes. Each eye is made of numerous units called ommatidia.

9. *Cilia* are absent in the animals.
10. Sexes are separate. Many arthropods show metamorphosis in the life cycle.

This phylum is divided into five classes namely (1) Crustacea (2) Myriapoda (3) Insecta (4) Arachnida and (5) Onychophora.

Class 1: Crustacea (e.g.) **Prawn.**

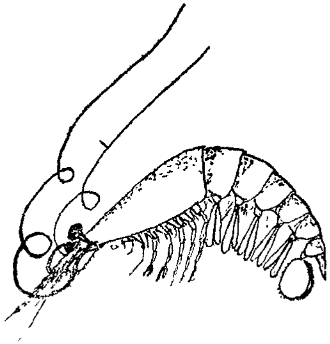

Fig. 20
Prawn

This is aquatic. Body is divided into three regions namely cephalon or head, thorax and abdomen. The number of segments is definite. The head has 5, thorax has 8 and abdomen has 6. The cephalic and thoracic segments have a common dorsal shield known as carapace. All segments bear a pair of appendages which are many jointed. There are sensory, feeding, walking and swimming appendages. Respiration is by gills. Sexes are separate. There are several larval stages in life history.

Class 2: Myriapoda (e.g.) Centipede and Millipede.

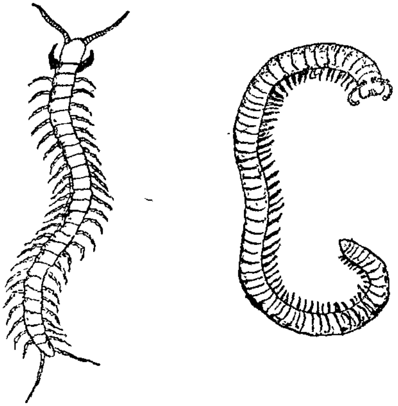

Fig. 21
Centipede **Millipede**

These are terrestrial animals. Body is many segmented. There is a distinct head with simple eyes and antennae. Segments bear a pair of appendages each in centipede, and two pairs of appendages each in millipede. Centipede is carnivorous, nocturnal and has a. pair of poison claws. Millipede is herbivorous, diurnal and has no poison claws. Respiration is by tracheal

tubes which open to the out side by spiracles. Sexes are separate and there is no larval stage.

Class 3: Insecta (Hexapoda) (e.g.) Cockroach, Grasshopper.

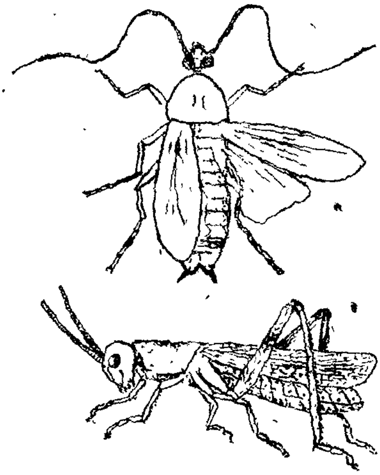

Fig. 22
A. Cockroach B. Grass-hopper

This is a very big class of Arthropoda and has several orders. A typical insect has its body divided into a head, a thorax and abdomen. Head carries a pair of compound eyes, and a pair of antennae. Many organs in the mouth help feeding and they are adapted suitably for different diets of different insects. The thorax has three segments and usually bears two pairs of wings and three pairs of jointed legs. Abdomen has ten segments with no appendages. Respiration is by tracheal system. Sexes are separate. There is usually metamorphosis in the life cycle.

Class 4: Arachnida (e.g.) Spider, Scorpion, Tick, Mites.

These arthropods have four pairs of legs. The front part or prosoma of the body has one pair of chelicerae, one pair of pedipalps and four pairs of legs. Antennae are absent. Paired simple eyes are present. Respiration is by tracheae or book lungs. Some are poisonous. In spiders the prosoma and opisthosoma are clearly separated. In ticks there is no such demarcation. Ticks are parasitic.

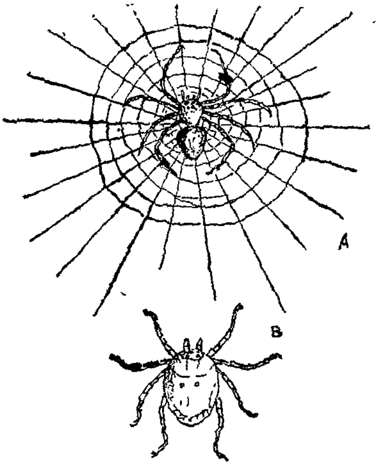

Fig. 23
A. Spider, B. Tick

Class 5: Onychophora (e.g.) Peripatus

Fig. 24
Peripatus

This class is now elevated as a sub phylum. The animal has some annelidan and some arthropodan characters. Animal shows discontinuous distribution.

Phylum Mollusca This phylum has many animals which have the following general characters.

1. Animals are soft bodied and unsegmented.
2. The body is enclosed by a fold of skin called the mantle.
3. The mantle usually secretes a calcareous shell.
4. The locomotor organ is a muscular organ called the foot.
5. The respiratory organs are usually the gills or branchiae or a 'lung' in terrestrial forms.
6. Nervous system consists of several pairs of ganglia and their connectives.

The phylum Mollusca is divided further into five classes namely (1) Amphineura (2) Scaphopoda (3) Pelecypoda (4) Gastropoda and (5) Cephalopoda.

Class 1: Amphineura (e.g.) Chiton

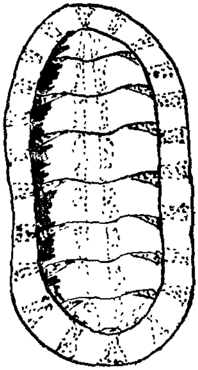

Fig. 25
Chiton

Animals are all marine. Body is bilaterally symmetrical. It is covered dorsally by eight pieces of shell. There is a broad ventral foot.

Class 2: Scaphopoda
(e.g.) Dentalium

It is popularly called tusk shell. The body is elongated and lacks a distinct head. The animal is a marine form often burrowing in sand. There is a single tusk shaped shell.

Fig. 26
Dentalium

Class 3: Pelecypoda or Bivalvia (e.g.) Lamellidens

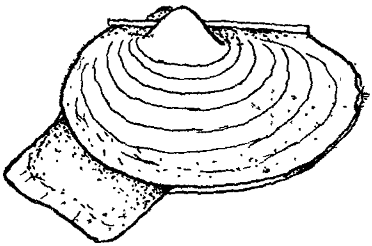

Fig. 27
Lamellidens

These animals are bottom dwellers in shallow waters. There are two shells hinged together dorsally. There is a muscular foot in front, which helps in locomotion. Animal feeds on microorganisms that are swept in, by a ciliary current.

Class 4: Gastropoda (e.g.) Pila

The animal has a spherically coiled shell. The foot is broad and has a creeping sole. The animal can withdraw into the shell and close up the opening with a lid called operculum. It has adaptations for aquatic and aerial respiration. The animal has in its mouth a rasping organ or a radula. Sexes are separate. There is no larval stage.

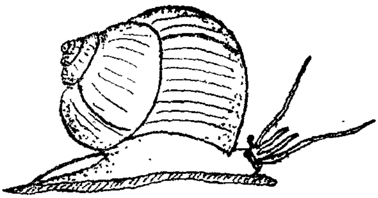

Fig. 28
Pila

Class 5: Cephalopoda (e.g.) Sepia

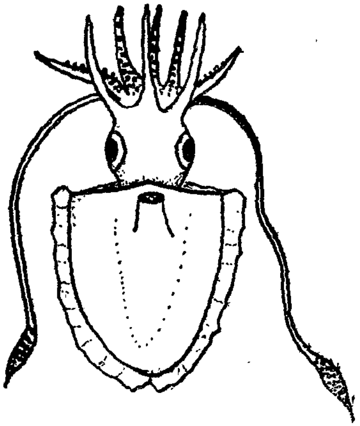

Fig. 29 Sepia

This is a marine animal. The body is bilaterally symmetrical. There is a distinct head with prominent eyes and oral arms. Shell is internal. The foot is modified into oral arms and the siphon. Sexes are separate. There is no larval stage.

Phylum Echinodermata This phylum comprises of animals with the following general characters.

1. All animals are marine.
2. Animals exhibit radial symmetry but the larvae show bilateral symmetry.
3. The skin is supported by calcareous plates or spicules and spines, hence the name echinodermata.
4. A peculiar system of canals, called water vascular system is present, in which sea water circulates.
5. The organs of locomotion are tube feet.
6. There are no definite excretory organs.
7. Respiration is by dermal branchiae.
8. Sexes are separate. There is a distinct larval stage.

The phylum is divided into five classes namely (1) Asteroidea (2) Ophiuroidea (3) Echinoidea (4) Holothuroidea and (5) Crinoidea.

Class 1: Asteroidea (e.g.) Star fishes.

The animals have a central disc and five radiating arms. Mouth is ventral and anus is dorsal. Numerous tube feet are present on the ventral side of the arms, on either side of a groove. Skin is full of spines, gills and pedicellariae.

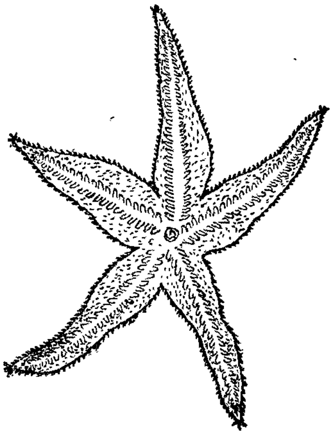

Fig. 30
Star-fish

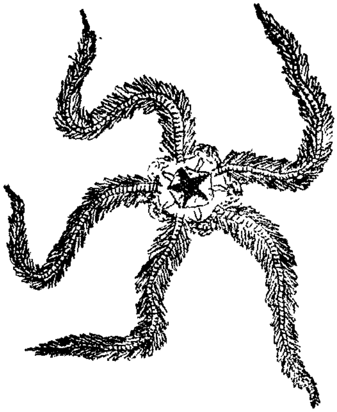

Fig. 31
Brittle star

***Class 2:* Ophiuroidea**

(e.g.) Brittle stars

The central disc is small.

The arms are long and narrow and they show independent movement.

Class 3: Echinoidea (e.g.) Sea Urchins

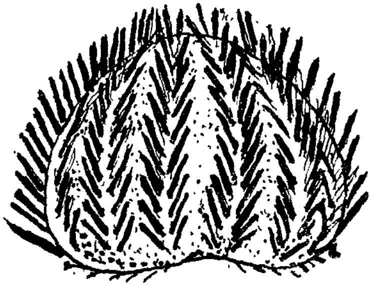

Fig. 32
Sea-Urchin

These are almost spherical. The mouth is ventral. Numerous long spines project from the body through the shell.

Class 4: Holothuroidea (e.g.) Sea Cucumbers

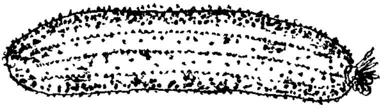

Fig. 33
Sea-Cucumber

These are found lying at the bottom of shallow reefs. The skin appears smooth but has numerous spicules embedded in it.

Class 5: Crinoidea (e.g.) Sea Lily.

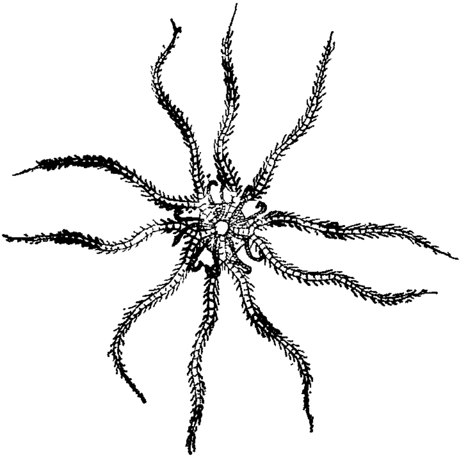

Fig. 34
Sea-Lily

These are attached forms. The arms appear as the leaves of palm trees. There are no suckers on tube feet and no pedicellariae.

Phylum Chordata This is a very big group of animals, which differs from the previous phyla by certain major differences such as

1. All animals have a median, dorsal, supporting rod called Notochord. This gives rise to backbone later, in higher chordates.

2. There are paired gill slits on the wall of the pharynx. These appear at least in embryonic stages.

3. The central nervous system is dorsal and tubular.

4. The heart is placed ventrally behind the pharynx.

5. There is a distinct hepatic portal system. (Blood from the alimentary canal is taken to the liver and from there, it is again taken to the heart).

6. There is a post-anal tail.

7. Animals do not have more than two pairs of limbs (limbs may be absent, but never more than two pairs)

8. The repsiratory pigment is found in the corpuscles of the blood.

This phylum has a subdivision called prochordates which include the Amphioxus and the Ascidian.

1. Amphioxus (Branchiostoma) Lanceolatus

Fig. 35

Amphioxus

This belongs to the division cephalo chordata. The animal lives half burried in the sandy bottom of the sea. The body is about 1 to 2 inches in length. It creates a current of water through its mouth and feeds on micro-organisms, that come in with the water. The pharynx has numerous gill slits. The endostyle, a special food capturing device is on the floor of the pharynx. The circulatory system is typical of a chordate animal. There is a long median notochord above the alimentary canal. A dorsal tubular nervous system is also present.

2. **Ascidian** represents the division urochordata or tunicata

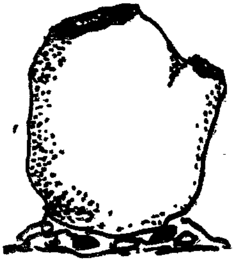

Fig. 36
Ascidian

These are sedantary animals in the sea. The larva has a notochord in the tail region. Later this disappears. Water is taken in through the mouth along with microorganisms. The pharynx has numerous gill slits and a food capturing organ, the endostyle. The circulatory system is peculiar because it flows in opposite directions alternately. Nervous system is very much reduced.

The subdivision vertebrata or craniata is divided into five big classes namely (1) Pisces (2) Amphibia (3) Reptilia (4) Aves and (5) Mammalia.

Class 1: Pisces (e.g.) Mugeil oeur. (Mullet)

This includes cartilagenous fishes like Shark and bony fishes like Mullet. The fishes have the following general features.

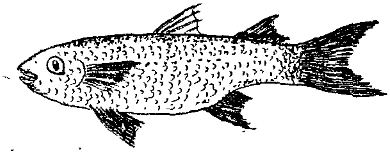

Fig. 37
Mugeil oeur (Mullet)

1. All are aquatic.
2. Body is covered by dermal scales.
3. Respiration is by pharyngeal gills.
4. Locomotion is effected by fins.
5. All are cold blooded.
6. Most of them are oviparous (egg-laying)
7. The heart has only two chambers namely one auricle and one ventricle.
8. The brain has a pair of vascular sacs and a pair of inferior lobes.

Class 2: Amphibia (e.g.) Rana hexadactyla (Frog).

This includes the toads, frogs, newts, salamanders and limbless forms like icthyophis. The animals of this class have the following features.

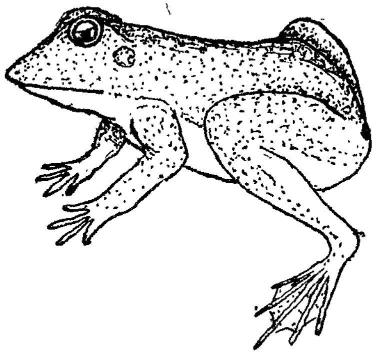

Fig. 38
Rana hexadactyla (Frog)

1. Animals are capable of living in water and straying on land also.
2. The body is covered by a smooth skin full of glands to help cutaneous respiration.
3. Both aquatic and aerial respiration are possible because skin and lungs are respiratory. In early larval stages gills are also present.
4. The animals have two pairs of limbs except in the case of apoda or gymnophiana.
5. All are cold blooded.
6. Animals are oviparous.
7. The heart has three chambers namely two auricles and one ventricle.
8. The early stages of life requires an aquatic environment. There is a metamorphosis.

Class 3: Reptilia (e.g.) Calotes versicolour (garden lizard).

This class includes many animals like lizards, snakes, turtles, tortoises, crocodile and the tuatara. The animals have the general features listed below.

1. All are terrestrial animals and they are adapted to it. (Turtles, crocodiles etc. have taken to water for feeding. They have to come out for breathing and breeding.)

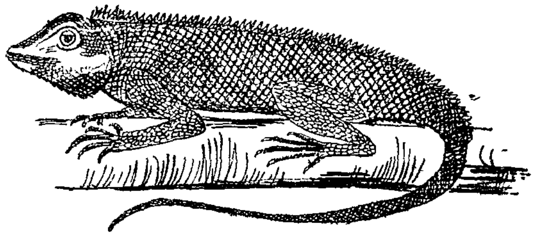

Fig. 39
Calotes versicolour (garden lizard)

2. Body is covered by epidermal scales.
3. Respiration is only by lungs.
4. Locomotion is by two pairs of limbs. The digits have claws. (In snakes limbs are absent.)
5. All are cold blooded.
6. Animals are oviparous.
7. The heart has two auricles and one ventricle which is imperfectly divided into two.
8. The embryo develops a bag like, liquid filled covering called amnion, in which the embryo floats.
9. The reptiles have organs for internal fertilisation.
10. Numerous teeth on jaw bones are found in both jaws.

Class 4: Aves (e.g.) Columba livea (Pigeon)

All birds come under this class. They are characterised by the following:

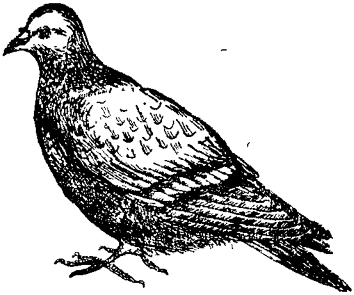

Fig. 40
Columba livea (Pigeon)

1. Animals are terrestrial or arboreal.
2. Body is covered by feathers, which are of epidermal origin.

3. Respiration is by lungs which have air sacs attached to them.
4. The forelimbs are modified as wings for flight. The hind limbs are anteriorly shifted for balance. Digits have claws and adapted for perching.
5. Birds are warm blooded (have a constant temperature irrespective of the surrounding).
6. They are oviparous.
7. Heart has four chambers, two auricles and two ventricles.
8. There is a development of amnion.
9. Fertilisation is internal, though there are no organs for internal fertilisation. In females the right ovary and oviduct are abolished.
10. Teeth are absent in the jaws. Jaws are modified into beaks.
11. Many bones are fused together and some are porous.
12. Parental care is evident by the nest building, incubating and feeding the fledglings.

Class 5: Mammalia (e.g.) Rattus rattus (Rat). This class has numerous animals which have the following general characters.

Fig. 41
Rattus rattus (Rat)

1. Animals are terrestrial except few like whales, dugongs, seals etc.
2. Body is covered by epidermal hairs.
3. Respiration is only by lungs.
4. There are two pairs of pentadactyle limbs differently modified in different groups. Digits have nails.

5. Mammals are all warm blooded.
6. Mammals are viviparous (*i.e.*) they bring forth young ones which have developed inside the mother's body.
7. The young are fed by the secretion of mammary glands (hence the name Mammals).
8. Heart has four chambers namely two auricles and two ventricles.
9. There is a development of Amnion during development.
10. Dentition is thecodont, heterodont and diphyodont.
11. There is a diaphragm separating the chest and the abdomen.
12. There is an external ear or pinna on either side of the head.
13. The urinogenital and anal openings are separate.
14. Parental care is evident.

CHAPTER III

Euglena viridis

Euglena viridis is an acellular or *non-cellular* organism found commonly in fresh water ponds and tanks, especially those *that* are rich in decaying organic matter. The animal is placed in classification as follows:

Kingdom	—	Animalia
Sub kingdom	—	Invertebrata
Phylum	—	Protozoa
Class	—	Mastigophora or Flagellata
Subclass	—	*Phytomastigna* or *Phytomastigophorea*
Order	—	Englenida
Family	—	Euglenidae
Genus	—	Euglena
Species	—	viridis

Structure:

The animal is spindle shaped with a blunt anterior end and a pointed *posterior* end. The shape is almost *constant* because of the cell membrane which is also called the periplast or pellicle. The nucleus is at the centre of the animal. The cytoplasm of the cell can be differentiated into an outer clear ectoplasm and an inner granular endoplasm. The ectoplasm is more in a 'gel' state and the endoplasm is more in a 'sol' state. The anterior *end of* the animal has a deep depression called the *gullet or cytopharynx. A long* thread like structure called the flagellum arises from the base of the gullet. This whip like flagellum is really made of two fibres called axial filaments or axonemes. These arise from two granular bodies inside the pellicle, which are called the basal granules or **blepharoplasts.** The flagellum looks *like an* elongated cilium, in having two central fibres

surrounded by 9 double fibres as seen in a cross section. The blepharoplasts are connected to the nucleus by a thickening of the cytoplasm called the **Rhizoplast.** There is a photoreceptive spot or light sensitive spot near the anterior end of the animal. This is called the eye-spot or **stigma.** This contains granules of a carotin pigment called **hematochrome.**

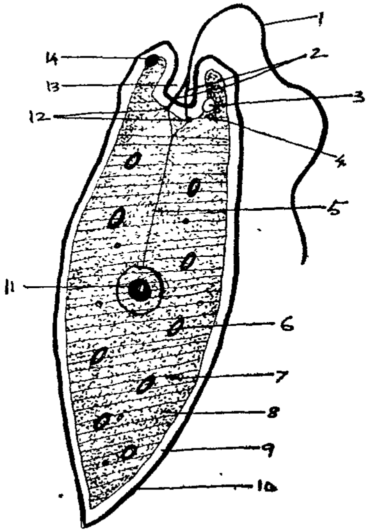

Fig. 42
Euglena viridis

1. Flagellum 2. Axoneme fibrils 3. Contractile vacuole 4. Formative vacuole 5. Rhizoplast 6. Chromoplast 7. Myoneme fibrils 8. Endoplasm 9. Ectoplasm 10. Pellicle 11. Nucleus 12. Basal granules 13. Gullet 14. Eye-spot.

There is a contractile vacuole near the gullet. It consists of a central reservoir and a number of small formative vacuoles around it. Very fine oblique striations are seen across the animal running on the surface. These are called **myoneme fibrils** and these are contractile. Inside the cytoplasm, there are numerous green plastids (chloroplasts) called chromatoplasts or chromatophores. These contain the green pigment chlorophyll characteristic of plant cells. Reserve food materials in the form of protein (pyrenoids) and starch (Paramylum bodies) are also seen in the cytoplasm, sometimes in close association of the chromatoplasts.

Locomotion: Euglena is an active free swimming animal. The whip like flagellum is the locomotor organ. The connection between the basal granules of the flagellum and the nucleus, by the rhizoplast, indicates a possible control of flagellar movements by the nucleus.

The flagellum bends to one side quickly, beating the water and slowly regains the original position. This movement causes the Euglena to move forward. The flagellum also exhibits a

rotating movement like a spiral, thereby propelling the Euglena forward.

Occasionally, Euglena shows a special type of movement characteristic of it. It is called Euglenoid movement or squirming movement. This wriggling movement is brought about with the help of the myoneme fibrils on the body. The body contracts at the posterior end and this contraction passes forwards as a wave and ends anteriorly.

Euglena is sensitive to light due to its eyespot or stigma. It is adapted to receive unidirectional light. Euglena is phototactic (*i.e.*) it moves towards light. However it avoids bright light just as it avoids darkness.

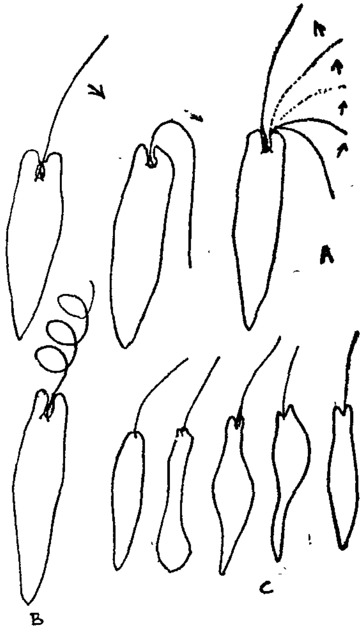

Fig. 43
Euglena-Locomotion
A. Stroke B. Spiral C. Squirming

Nutrition: All Organisms require food. Euglena obtains its food in three different ways.

1. Holophytic nutrition: Euglena can manufacture food just like green plants by photosynthesis. The chromotoplasts contain chlorophyll pigment which enables the animal to synthesise food, from CO_2 and water using solar energy. The sunlight is used to photolyse the water and then to synthesise glucose with the help of CO_2. Glucose is then polymerised into starch.

2. Holozoic nutrition: Euglena is believed to ingest or swallow micro organisms through its gullet and use them as prey to be digested intracellularly. However convincing proofs are yet wanting to establish this method of feeding.

3. Saprophytic or Saprozoic nutrition: In the absence of light, Euglena obtains nourishment by this method. The animal

produces enzymes which digest dead organic matter in the surrounding water. Then the digested food is absorbed through the body surface. *If Euglena are kept in dark, the green colour also disappears.*

Respiration: This takes place by direct diffusion of gases through the body surface. *The oxygen in the water diffuses* into the animal and CO_2 diffuses out.

Excretion and Osmoregulation: This is carried on by the contractile vacuole. The metabolic waste products and the excess of water, that enter the animal's body, through osmosis, are collected by the small formative vacuoles first. Then these pass on the material to the central reservoir which then opens into the gullet. From there, the waste and excess of water reach outside.

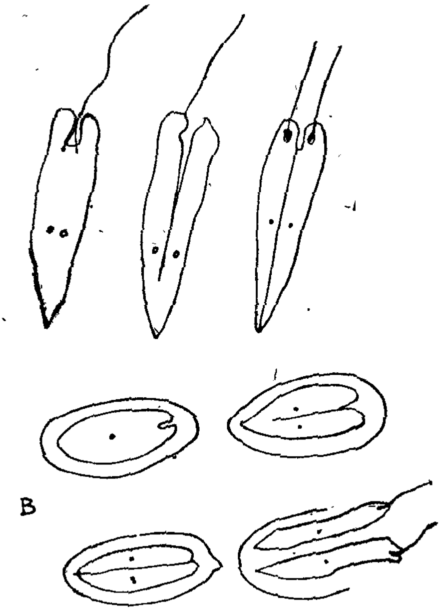

Fig. 44
Euglena-Reproduction
A. Binary fission B. encystment

Reproduction: Euglena reproduces generally by binary fission. First, the nucleus divides into two by mitosis. Then the *cytoplasm divides. This division starts from the anterior end.*

The flagellum is retained by one half and the other half develops a new flagellum. The division is always along the long axis.

During unfavourable conditions such as drought, the animal loses its flagellum and develops a hard protective wall around itself. This is called the cyst wall. Inside the cyst, the animal lives with a reduced metabolic rate. Binary fission takes place, longitudinally inside the cyst. When favourable season returns, the cyst wall breaks. Both the individuals develop flagella and swim out. The cyst formation helps to overcome the hard days and to get dispersed from pond to pond.

CHAPTER IV

Hydra vulgaris

Hydra vulgaris is a common multicellular organism found in fresh water ponds and streams. The animal is placed in classification as follows.

Kingdom	—	Animalia
Sub kingdom	—	Invertebrata
Phylum	—	Cnidaria (Coelenterata)
Class	—	Hydrozoa
Order	—	Hydroidea
Suborder	—	Athecata
Family	—	Hydridae
Genus	—	Hydra
Species	—	vulgaris

The hydra is formed of numerous cells and so it is called a multicellular animal. The animal lives attached to the leaves of water plants. The animal has a cylindrical body with a flat base. The base is attached to the substratum. The free end of the animal has the mouth, which is surrounded by a number of finger like tentacles. The mouth is at the tip of a small conical part called oral cone or hypostome.

The body wall of the hydra is made of two layers of cells namely the outer ectoderm and the inner endoderm. So the animal is said to be a diploblastic animal. The various cells of the animal's body undergo modifications to carry out specific functions. They get organised into various tissues. So the hydra is said to belong to a tissue grade of organisation.

The mouth leads into a central cavity called coelenteron or gastro vascular cavity. The body cavity (coelom) and the alimentary cavity (enteron) are one and the same.

In between the ectoderm, or outer layer of cells and the endoderm or inner layer of cells, there is a jelly like substance called mesoglea. The cells of hydra are of different types.

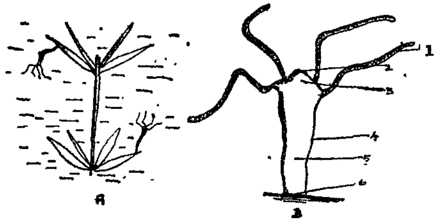

Fig. 45
(A) Hydra (B) Hydra (enlarged)
1. Tentacle 2. Mouth 3. Hypostome
4. Body wall 5. Coelenteron 6. Base

1. Musculo-epithelial cell:

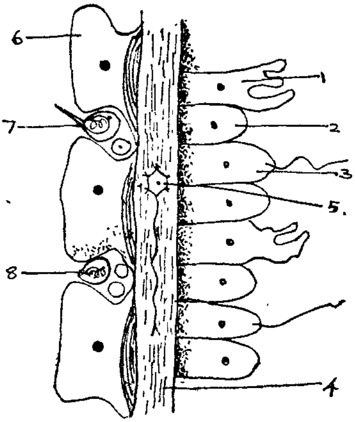

Fig. 46
L. S. of Body Wall
1. Amoeboid cell 2. Secretory cell
3. Flagellated cell 4. Mesoglea
5. Nerve cell 6. Musculo-epithelial cell
7. Stinging cell 8. Interstitial cell

These are found in the ectoderm. They are conical or pear-shaped with their broader ends directed towards the outer side forming the covering of the body. Their narrower ends face inwards and are extended and muscularised. The muscle fibres run lengthwise in the animal like longitudinal muscles. The contraction of these fibres cause shortening of the animal or bending the body from side to side.

2. Interstitial cells: These cells are found in between ectodermal cells. These cells are like reserve cells. They can get modified into any type of cell to make good cells, lost or damaged. Some of these cells become modified as stinging cells or Nematocysts characteristic to this phylum.

3. Nematocysts or Stinging cells: These cells are found only in animals of this phylum. Some of the interstitial cells

give rise to these cells. Such cells are called cnidoblasts. The nematocysts help hydra to kill the prey and in defence.

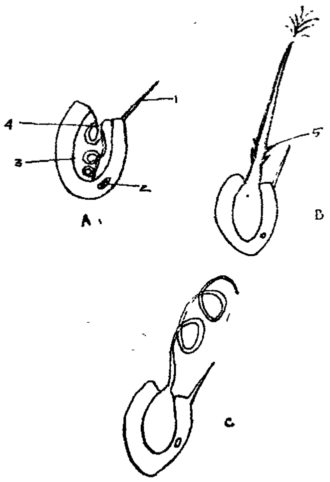

Fig. 47
Stinging cells
1. Cnidocil 2. Nucleus
3. Cnidoblast 4. Hollow thread
5. Barbs A. Nematocyst at rest
B. Nematocyst in action
C. Volvent

Each nematocyst has a hollowed cell with a nucleus to one side. A hollow coiled thread is involuted inside the cavity which is filled with a toxic or poisonous fluid called hypnotoxin. There is a sensitive hair like projection from one corner of the cell. It is called cnidocil. If this cnidocil is irritated, the cell bursts out pushing or everting the hollow thread, through which the poisonous fluid flows. There may be a few sharp spine like barbs at the base of the thread to help piercing the tissue of the prey. These cells with barbs are called penetrants. Some others do not have the barbs but the thread coils like a tendril around the prey to immobilise it. Such cells are called volvent cells. A third type of cell called glutinant produces a sticky fluid through the hollow thread and helps fixation or adhesion. These cells are usually stimulated chemically and not by nervous system. The stinging cells or nematocysts help hydra in capturing and paralysing the prey. The stinging cells are absent in the base but are found in large numbers in the tentacles. They are referred to as batteries of stinging cells.

4. Adhesive cells: Some interstitial cells at the base of the hydra secrete a sticky substance to help fixing the hydra to the substratum. These also help in gliding movement of the hydra.

5. Nerve cells or Neurons: Some interstitial cells modify themselves as nerve cells or neurons to help in communication. These cells sink into the mesoglea and form a network of nerves.

Each nerve cell has an irregular cell body or cyton with a nucleus. The cytoplasm is rich in Nisslis granules. The corners of the cell are produced into short branched tree like processes called dendrites through which messages enter the cell. From one corner of the cell arises a long fibre called Axon fibre through which messages leave the cell. If there is only one axon it is called unipolar cell; if two bipolar, and if three tripolar cells and so on. The axon fibre is insulated by two coats namely a myelin sheath inside and a neurilemma outside. The investments leave uncovered nodes inbetween called nodes of Ranvier. In hydra all nerve cells are interconnected like a network.

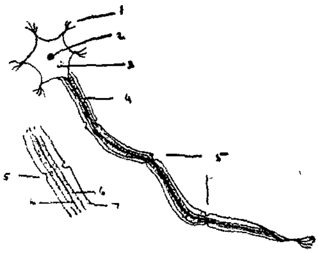

Fig. 48

Nerve cell

1. Dendrites 2. Nucleus
3. Nissl's granules 4. Axon
5. Nodes of Ranvier
6. *Myelin sheath*
7. Neurilemma

6. Male cells or Sperms: Some of the interstitial cells multiply rapidly to give rise to the testis which produces male cells by meiosis.

7. Female cells or Ova: Similarly some of the interstitial cells give rise to the ovary, inside which a single ovum or egg cell is organised after meiotic division.

Endoderm cells

The cells forming the inner layer of cells in hydra are called endoderm cells.

The endoderm cells have their lower part muscularised like the ectoderm cells, but here the fibres run perpendicular to the direction of muscle fibres of the ectoderm. The contraction of these fibres of the endoderm will squeeze the hydra and elongate it. *i.e.* these act as circular muscles.

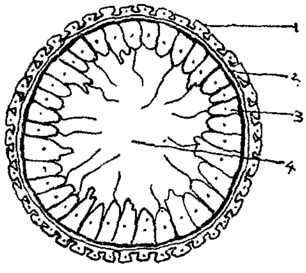

Fig. 49

C.S. of Hydra

1. Ectoderm 2. Mesoglea
3. Endoderm 4. Coelenteron.

There are three types of cells in the endoderm. They are 1. Amoeboid cells 2. Secretory cells and 3. Flagellated cells.

8. **Amoeboid cells** are capable of putting forth pseudopodia to engulf food particles.

9. **The secretory cells** secrete digestive enzymes into the coelenteron to break down the food.

10. **The flagellated cells** possess long whip like flagella which keep the fluid inside coelenteron in constant movement so as to circulate food particles to all regions of the body.

Thus the hydra has ten different types of cells in its body. The various cells have divided among themselves the various jobs that have to be done. This phenomenon is called division of labour.

Locomotion: Hydra is generally a sedentary animal. It rarely moves from place to place; because it gets its food from wherever it is. But occasionally it has to change its location in a bid to change the venue of its feeding ground. To this end it has developed methods to shift its location. Four types of movements have been reported.

1. **Gliding:** The hydra glides on the surface of its substratum. The secretory cells at the base secrete a mucus like substance and the musculo-epithelial cells effect a gliding movement using the mucus.

2. **Somersault movement:** The hydra elongates to the maximum extent and bends down. The tentacles get attached to the substratum and the base is lifted up. Now the hydra is upside down. Then, the base is brought down on the other-side and the oral end is lifted up. Thus hydra can execute somersaults several times and move quickly on the surface.

3. **Caterpillar like looping movement:** Hydra extends to its full length and bends down catching hold of the substratum by its tentacles. Then the base is drawn near the oral end. Then the oral end is lifted and fixed in a different position. The action is repeated. This resembles the movement of the caterpillar.

4. Floatation: Sometimes the hydra secretes a gas bubble at its base. This bubble comes to the surface of the water and

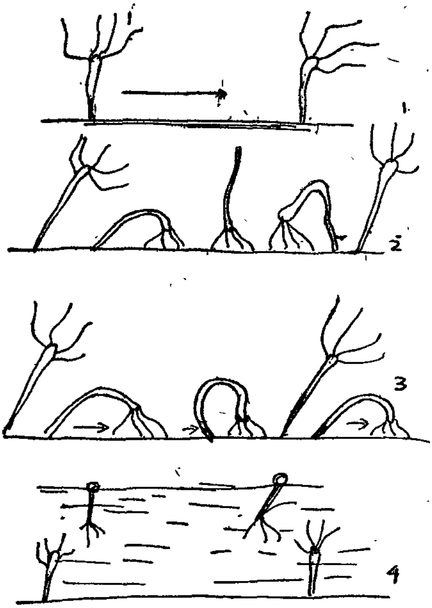

Fig. 50
Hydra-Locomotion
1. Gliding 2. Somersault 3. Caterpillar like 4. Floatation

the hydra can be seen hanging upside down from the bubble. The bubble may be wafted here and there on the water surface. After some time the gas is absorbed or the bubble breaks off dropping the hydra in a new location.

Nutrition

Hydra feeds on small aquatic organisms like the water flea (Daphnia). These organisms swarm in water and are caught and eaten by the hydra. There are numerous stinging cells in the tentacles of the hydra. When a water flea happens to touch the cnidocil of a stinging cell, the nematocyst explodes. The dart comes out, pierces the body of the prey and injects the toxic substance into it. The prey is paralysed and then drawn into the mouth of the hydra. Inside the coelenteron the prey is subjected to the action of digestive enzymes secretd by the secretory cells of the endoderm. These cells are more

numerous near the mouth region. The prey is acted upon by the enzymes and it is broken down into smaller particles. As this part of digestion takes place outside the cells, it is called extra cellular digestion. Then the flagellated cells cause a stirring movement by their flagella. The water inside the coelenteron along with food particles is distributed throughout the coelenteron. The amoeboid cells in the endoderm put forth pseudopodia and engulf these food particles. These become food vacuoles inside these cells. Inside the vacuole. first acidic enzymes and then alkaline enzymes are secreted. The food particle is digested and absorbed. This part of digestion is known as intracellular. Thus digestion in hydra is partly extracellular and partly intracellular. The absorbed food is shared by all cells.

The undigested matter, if any, is left back in the coelenteron and has to be expelled out of the body through the mouth itself as there is no other opening. This usually happens when the animal contracts violently.

Respiration: All cells in hydra are in contact with water. The oxygen in the water diffuses into the cells and CO_2 diffuses out.

Excretion and osmoregulation: Each cell has its own contractile vacuole which performs the work of removal of waste and excess of water from the cells.

Nervous system: There is no centralised brain in hydra. There is a loose net work of nerve cells distributed throughout the body wall. This nerve net flashes all messages throughout the body. Perfect coordination of various activities are brought about by this nervous system.

Reproduction: Hydra reproduces both asexually and sexually.

Asexual or Vegetative reproduction

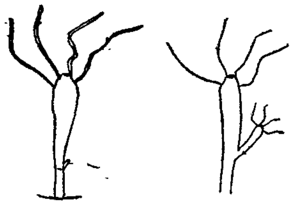

Fig. 51
Hydra-Budding

This is also called Budding. The body wall of the hydra projects out like a small bud. This projection is formed by the whole body wall with ectoderm, endoderm and mesoglea. The coelenteron also extends into the bud. The bud gradually elongates as a branch

with a closed end. After the branch is well formed, it develops a mouth at its free end. A number of tenatacles arise around the mouth of the branch and a small hydra is formed. Still this daughter hydra retains the connection with the coelenteron of the mother. Very slowly the daughter is then constricted off the mother to become an independent individual. Sometimes, the bud may give rise to more buds even before it is separated from the mother hydra.

Sexual reproduction: Hydra is a hermaphrodite (*i.e.*) it is an animal which has both male and female reproductive organs in the body of the same individual.

The sex organs or gonads are developed by the interstitial cells of the ectoderm. The male sex organ is called the testis or spermary. It is usually formed in the upper half of the animal. The interstitial cells start multiplying rapidly and soon a bulge appears in the ectoderm. Inside the swelling, sperms or male cells are organised. One of the divisions is a reduction division and so all the sperms have only one half of the chromosomes as the ordinary cells. When the sperms are ready the testis breaks open and the sperms are released outside.

The female sex organ is called the ovary. This is usually formed in the lower half of the animal. Here also it is given rise to by the interstitial cells but only one ovum develops. The ovum is also formed by reduction division and it has also one half of the number of chromosomes as the ordinary cells. When the ovum is ready for fertilisation it is released into the water.

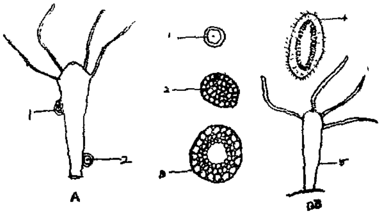

Fig. 52

Hydra Sexual reproduction

A. 1. Testis 2. Ovary

B. 1. Zygote 2. Blastula 3. Gastrula
4. Planula 5. Young hydra

Fertilisation takes place in water. Only one sperm fertilises the ovum. The fertilised ovum divides mitotically and soon forms a hollow ball of cells called a Blastula. Then the cells arrange themselves in two layers (an ectoderm and an

endoderm) enclosing a central cavity called the archenteron (gastrovascular cavity). The outer cells develop cilia and the young animal (planula larva) swims in water and then settles down. A mouth and tentacles are developed at the free end and a young hydra is formed.

Regeneration: If any part of the hydra is cut off accidentally, the animal will grow the lost part. This capacity is known as regeneration. Even if the hydra's free end with the mouth and tentacles are cut off, the animal will develop a new mouth and tentacles.

CHAPTER V

Taenia solium

(Tape worm)

Taenia solium, commonly known as the tape worm, is a parasite *living in the intestines of man. It is placed in classification* as follows:

Kingdom	Animalia
Sub kingdom	Invertebrata
Phylum	Platyhelminthes (flat worms)
Class	Cestoda
Subclass	Eucestoda
Order	Taenioidae
Family	Taeniidae
Genus	Taenia
Species	solium

The tapeworm is a parasite (A parasite is an animal, that lives at the cost of another living organism, often causing inconvenience to the host) It lives in the cavity of the intestines of many mammals. In man, it is common among pork eating people.

The tapeworm gets its popular name, by its appearance, like a flat ribbon or tape. The animal lives attached to the inner wall of the intestine. The attachment is effected by a small head like part called the scolex. The body appears as a string of numerous segments called proglottids.

The scolex has a flat round top called the rostellum. It is surrounded by a set of sharp recurved hooks. These help to fix the scolex firmly to the wall of the intestine. The scolex also has four suckers on the four sides. Each sucker is a muscular structure operating on the principle of a vacuum cup. These also help in fixation. Such firm fixation is necessary, as otherwise the oncoming food in the intestines will push the parasite out.

The body of the tapeworm is covered by a special cuticle, which resists the action of digestive enzymes of the host, by producing certain anti enzymes. Otherwise the parasite itself will be digested by the host.

Locomotor organs such as legs, and sense organs such as eyes, are absent as they are of no use inside the dark intestines of the host. The alimentary system is also totally absent, as the parasite can absorb, the digested food of the host directly.

The proglottids near the scolex are small and this region called the neck, gives rise to new segments. The older proglottids are at the rear end.

Each proglottis contains a complete set of organs. The cross section of the body of the tapeworm shows an outer cuticle, and circular and longitudinal muscles forming the body wall. The central part is occupied by loosely arranged parenchyma cells and therefore there is no body cavity. The other organs lie embedded in this parenchyma.

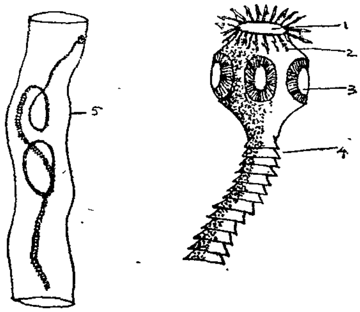

Fig. 53
Taenia solium-Scolex
1. Rostellum 2. Hooks 3. Sucker
4. Neck 5. Intestine wall

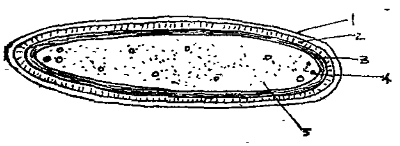

Fig. 54
C.S. of Tapeworm
1. Cuticle 2. Epidermis
3. Muscular layer 4. Lateral nerve cord
5. Parenchyma

Nutrition: As the animal is a parasite which absorbs the digested food materials of the host, there are no digestive organs in the animal. This is an adaptation to extreme parasitism.

Respiration: Tapeworm lives in a place where free air and oxygen is rare. So it is believed to have an anaerobic method of respiration, using the glucose available in the food, to get the necessary energy.

Excretion: The excretion is carried on by some special cells called flame cells or solenocytes. These cells are characteristic of the animals in this phylum.

Each flame cell is a hollowed out cell, the hollow of which contains a bundle of cilia. The cilia exhibit a movement which resembles the movement of a flickering flame. Hence the name flame cell or solenocyte. These cells are all connected to 4 longitudinal excretory canals 2 on either side. The two dorsally placed canals stop with a few anterior proglottids. The other two extend throughout the length of the worm ending in the last proglottis as the excretory pores. In every proglottis the two lateral canals are interconnected by a transverse duct at the posterior end of the proglottis. These excretory canals and the flame cells are also useful to maintain the water balance (osmoregulation) of the animal in relation to its environment. If the last proglottis breaks off, as it happens when it is gravid or full of eggs, then the excretory canals open at the end of the proglottis which becomes the last.

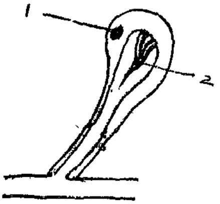

Fig. 55
Flame cell
1. Nucleus 2. Cilia

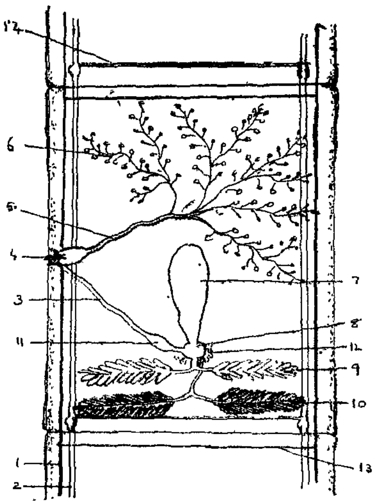

Fig. 56
Proglottis
1. Lateral nerve 2. Excretory canal 3. Vagina 4. Cirrus 5. Vas-deferens 6. Testis 7. Uterus 8. Ootype 9. Ovary 10. Vitelline gland 11. Receptaculum seminis 12. Shell gland 13. Nerve connective 14. Excretory canal connective

Nervous System: There is a pair of ganglia in the scolex. Two lateral nerve cords extend from the scolex to the posterior end of the worm. In every proglottis, the two nerve cords are connected across towards the anterior end. Sense organs such as the eyes are totally absent.

Reproduction : Every proglottis has a complete set of male and female reproductive organs. The male system has numerous small testis distributed mainly in the anterior part of the proglottis. Small tubes, called vasa efferentia collect the sperms from the testis and join together forming a single vas deferens. This tube runs towards a side of the proglottis where it opens at the genital pore. Before opening out it joins an intromittent organ the penis or cirrus, which can be retracted into a cirrus sac. The genital opening may be on the right side or on the left side of each proglottis.

The female system consists of two ovaries placed posteriorly in the proglottis. These are connected by short oviducts to a common chamber called the ootype. This ootype communicates with the genital pore by a canal called the vagina. Near the ootype the vagina is slightly enlarged to form the seminal receptacle. Two glands known as vitelline glands, placed behind the ovaries are also connected to the ootype. These glands secrete a nutritive substance (yolk) which is added on to the eggs. A few shell glands are also seen near the ootype which produce the shell for the eggs. The fertilised eggs are stored in a blind tube like process called uterus. This is attached to the anterior end of the ootype.

Fertilisation may be between different proglottids of the same worm. The sperms are introduced into the vagina and they reach the ootype and fertilise the eggs. The fertilised eggs are stored in the uterus. As more and more eggs gather in the uterus, it enlarges, often giving rise to branches. By this time the male organs atrophy. The uterus and its branches occupy almos- the entire proglottis. Such a ripe proglottis is called gravid progt lottis. Usually the last proglottis is gravid first. This is then cut off from the rest of the worm and is sent out of the host along with his faeces.

These gravid proglottids are taken in by the pig when it takes in human faeces. In the stomach of the pig the eggs are released. By this time some development has taken place and the eggs hatch as hexacanth embryos. These are globular structures with 6 hooks.

That is why they are called hexacanth embryos or onchospheres. These bore through the wall of the alimentary canal of the

pig and reach voluntary muscles through the blood stream. Once these reach the muscles, they lose the hooks and become encysted. Inside the cyst an invagination develops in the embryo. The invagination deepens and at the bottom evagination starts. The evaginated part is organised into a scolex and the neck. This part emerges out and the larva now appears as a small tape worm with a bladder attached behind. So, it is called the bladder worm or cysticercus stage.

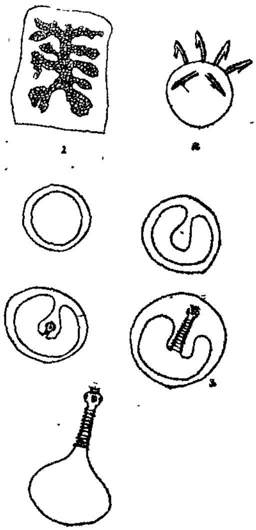

Fig. 57

1. *Gravid proglottis*
2. **Hexacanth embryo**
3. **Cysticercus**

Further infection of man occurs when he takes pork which is not properly cooked. Thus the tape worm has two hosts, man and the pig. The pig is called intermediate host and man as the definitive host. The parasite does not cause serious damage to the host. At times when infection is heavy anemia accompanied by Neurosis may result.

CHAPTER VI

Ascaris lumbricoides

Ascaris lumbricoides is also a parasitic worm, commonly known as the roundworm or threadworm. It lives in the intestines of man. It is placed in classification as follows:

Kingdom	—	Animalia
Sub kingdom	—	Invertebrata
Phylum	—	Nemathelminthes (Aschelminthes)
Class	—	Nematoda
Order	—	Ascaroidea
Family	—	Ascaridae
Genus	—	Ascaris
Species	—	lumbricoides

The parasite ascaris is called a round worm because it is cylindrical and long (*i.e.*) (a cross section is a circle or round). There is no segmentation of the body. The anterior and the posterior ends are tapering. The worms show sexual dimorphism *i.e.* the male and the female show external differences in size and shape. The female is longer, and has a straight posterior end. The male is smaller and has a curved posterior end. Besides, the genital opening and the anus are separate in the female, but in the male, there is a common opening called the cloaca.

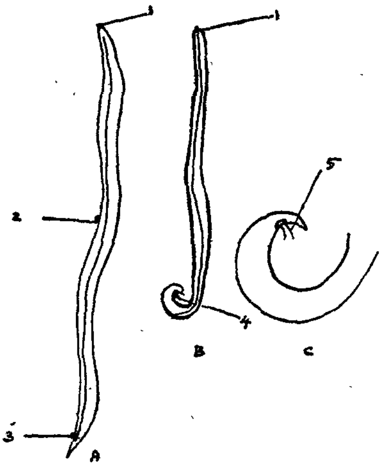

Fig. 58

A. Female B Male C Male hind end 1. Mouth 1 Mouth 2. Genital pore 3. Anus 4. Cloaca 5. Copulatory spiculus.

As the parasites live inside the intestines of man, many adaptations to that environment are seen. There are strong organs for fixation. There are three fleshy lips encircling the mouth. One is dorsal and the other two are ventro-lateral in position. The lips have papillae, and have tooth like edges with which the parasite gets a strong-hold on to the intestinal wall of the host. This is necessary to prevent being pushed out by the oncoming food.

The body wall has an enzyme resistant cuticle which also produces anti-enzymes to counteract the digestive enzymes of the host, as otherwise the parasite itself will be digested by the host.

Locomotor and sense organs are absent. Though there is an alimentary canal, special digestive glands are absent as pre-digested food of the host is available in plenty. Reproductive rate is also very high to obviate the risks involved in the life cycle.

The cross section of the worm shows an outer cuticle and below it is an epidermis. There are no cross walls in epidermis and it appears multinucleate. So it is called a syncytial layer. Beneath the epidermis are muscle cells. The epidermis shows four longitudinal bulgings inside, one dorsal, one ventral and two lateral in position. The lateral thickenings contain the excretory canals and the dorsal and ventral bulgings contain nerve cords.

The muscle cells are peculiar. Their peripheral ends are muscularised and their inner ends, look amoeboid. These processes are directed towards either the dorsal or the ventral nerve cords. The body cavity is occupied by a few giant cells which contain intracellular large vacuoles. The body cavity therefore is called a pseudocoelom. The alimentary canal is enclosed by a layer of columnar cells. The body cavity may show sections of testis and vas deferens in the male and ovaries and uteri in the female.

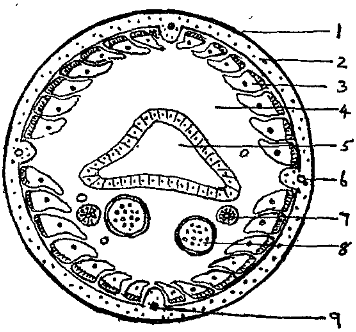

Fig. 59

C.S. of Ascaris Female

1. Cuticle 2. Syncytial epidermis 3. Muscle cell 4. Pseudocoelom 5. Intestine 6. Excretory canal 7. Ovary 8. Uterus 9. Nerve cord

Nutrition: The parasite nourishes itself mainly on the predigested food of the host. But, the food passes through the alimentary canal and the undigestible food for the parasite comes out through the cloaca or anus as the case may be. The alimentary canal has a mouth bordered by three lips and a small buccal cavity which leads into a muscular pharynx. The pharynx appears triangular in a section with its cavity like a triradiate lumen. The wall of the pharynx is muscularised in order to suck in the food. The intestine that follows is straight and long and it ends in rectum. In the female the rectum opens to the outside by the anus which is just in front of the posterior end ventrally. In the male the rectum joins the cloacal opening in the curved posterior region.

Respiration: As oxygen is scarce inside the host's intestine, the parasite resorts to anaerobic respiration.

Excretory System: Excretion is effected by two longitudinal excretory canals placed inside the lateral thickenings of the epidermis. The two canals join together in front below the pharynx and has a common outer opening ventrally called the excretory pore. There are no flame cells in ascaris. These excretory canals collect the waste and pass them out through the excretory pore.

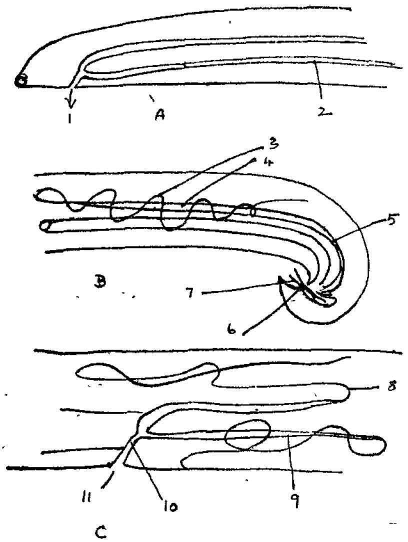

Fig. 60

A. Excretory canals. 1. Excretory pore
2. Excretory canal
B. Male: 3. Testis
4. Vasdeferens 5. Seminal Vesicle
6. Cloaca 7. Copulatory spicules
C. Female: 8. Ovaries 9. Uteri
10. Vagina 11. Genital pore

Nervous System: There is a nerve ring around the pharynx in front. It gives rise to 6 pairs of nerves, three pairs in front and 3 pairs behind. But only two nerve cords are long and extend to the whole

length of the animal. These are placed inside the dorsal and ventral thickenings of the epidermis. These two cords are connected at intervals by looplike connectives. There are no special sense organs.

Reproduction: Sexes are separate and the worms show sexual dimorphism. The male has a single long thread like testis. This is continued by the vas deferens which enlarges further down as seminal vesicle. This is connected to the cloaca. Near the cloaca, there is a sac containing a pair of copulatory spicules, which emerge and help in transfering the sperms to the female.

The female has a pair of thread like ovaries. These are connected to two oviducts which enlarge to become two uteri. The two uteri join ventrally to form a short vagina, opening at the female genital pore which is present about the middle of the body. The adult female lays a large amount of eggs, nearly a little more than 2 lakhs every day. This enormous reproductive rate is to compensate the risks involved in reaching new hosts.

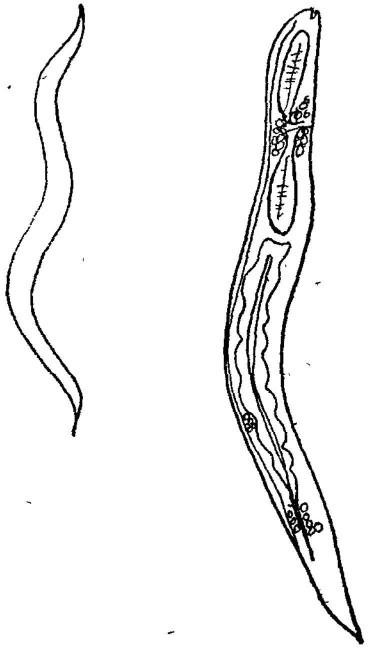

Fig. 61
Rhabditiform larva

The fertilised eggs are very small and they come out of the host along with his faeces. The embryos inside the eggs start developing and reach new hosts by contamination by water or food. The housefly which visits faecal matter and the dining dishes without any compunction is the potential source of contamination.

The eggs on reaching the duodenum of the new host hatch and small larvae come out. These are called RHABDITIFORM larvae. These pierce through the epithelium of the gut and reach the blood. Along with the blood the larvae go to the liver, and from there

to heart and then to the lungs. These then come out of the blood and climb up the air passages to reach the pharynx from where they again reach the intestines. There they establish themselves and grow into adult worms.

The migration of the larvae from the duodenum to the blood, liver, heart, lungs and then back to the intestines is called extra intestinal migration. Why does this migration take place, has not been satisfactorily explained so far.

The parasite in large numbers may cause obstruction to the passage of food and allied disorders. The larvae may get encysted in various parts of the host, like in the liver, kidneys, lungs and even in the brain, thus causing many disorders.

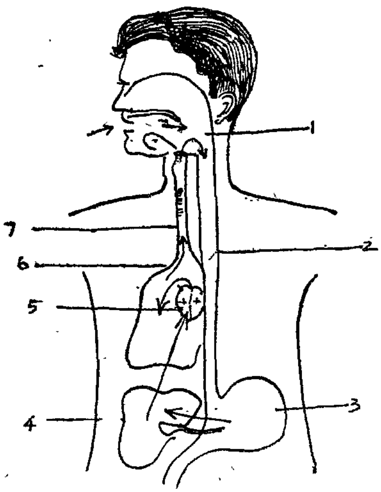

Fig. 62
Extra Intestinal migration
1. Pharynx 2. Oesophagus
3. Stomach 4. Liver
5. Heart 6. Lungs 7. Trachea

There are many drugs to kill the parasites inside the host, like santonin, oil of chenopodium, antipar, etc.

CHAPTER VII

Megascolex mauritii

(Earthworm)

The earthworm is a good representative of the coelomate animals. It occurs in moist soils in small burrows. The animal is generally nocturnal in habit. As the animal makes burrows in the soil, it helps aeration of the soil, which is very good for plants. That is why it is called "the friend of the farmer." It is placed in classification as follows.

Kingdom	Animalia
Sub kingdom	Invertebrata
Phylum	Annelida
Class	Chaetopoda
Subclass	Oligochaeta
Order	Terricolae
Family	Megascolacidae
Genus	Megascolex
Species	mauritii

The body of the earthworm is cylindrical and is marked into numerous segments. The markings are not only external but also internal. All the segments have more or less the same arrangement of organs inside. This type of repeated arrangement in every segment is called **metamerism.** There is a true body cavity or coelom inside.

Any two segments are separated by a small constriction called the intersegmental groove. There is a definite anterior and a posterior end. The mouth is in the centre of the first segment which is called the peristomium. Overhanging the mouth, in front of it, there is an upper lip like structure called the prostomium. The anus is in the centre of the last segment called the pygidium. The segments 14, 15, 16 and 17 secrete a hard ring like covering around themselves called the clitellum.

Behind the clitellum the numer of segments is indefinite running to 80 or 100. Dorsally every intersegmental groove behind the 10th segment bears small holes called dorsal pores, through which the body fluid exudes to keep the skin moist. The dorsal pores are absent in the region of the clitellum. The animal is a hermaphrodite. The male reproductive openings are found ventrally on the 18th segment one on either side. The female reproductive openings are found ventrally on the 14th segment often enclosed in a ridge. Small excretory openings called nephridiopores are present in some segments but they are too minute to be seen. All segments have small chitinous setae embedded in the skin. These can be extended or retracted by muscles.

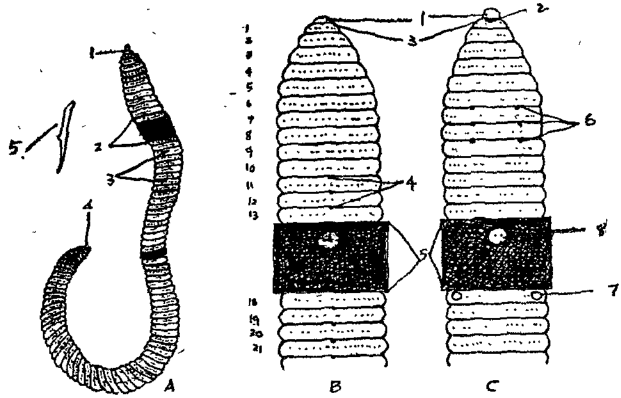

Fig. 63

A Earthworm
1. Mouth 2. Clitellum 3. Dorsal pores 4. Anus 5. Body seta
B. *Earthworm dorsal view* C. *Ventral view*
1. Prostomium 2. Mouth 3. Peristomium 4. Dorsal pores
5. Clitellum 6. Spermathecal openings 7. Male openings
8. Female openings

A cross section of the earthworm shows the following details. There is a cuticle on the outside secreted by the underlying epidermis. This is protective in function. The epidermis supports several chitinous setae embedded in sacs. The setae are slightly bent rod like structures with a swelling in the centre. Below the epidermis circular and longitudinal muscles are present. The alimentary canal is lined by endodermis and muscle layers. The cavity between the body wall and the alimentary

canal is called the body cavity or coelom. This contains blood vessels, nerve cords and nephridia.

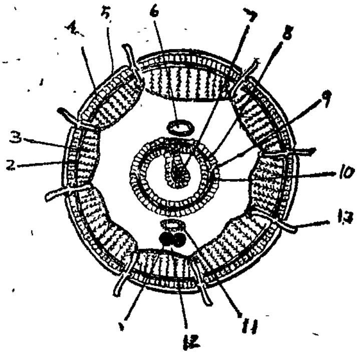

Fig. 64

C.S. of Earthworm

1. Nerve cord 2. Circular muscles
3. Longitudinal muscles 4. Epidermis
5. Cuticle 6. Dorsal blood vessel
7. Typhlosole 8. Muscle layer
9. Chlorogogen cells 10. Intestine
11. Ventral blood vessel 12. Coelom
13. Body setae

Locomotion: The earthworm creeps with the help of circular and longitudinal muscles. The body setae also help in locomotion. First the hind part of the body is anchored to the substartum by extruding bod setae. The circular muscles contract and longitudinal muscles relax. This causes extension of the body forwards as the hind part is fixed. After full elongation the anterior part of the body is anchored with the help of setae and then the circular muscles relax and longitudinal muscles contract. The setae in the posterior regions are retracted and the part is pulled forwards. Thus by wave like contractions the body moves forward.

Earthworm is sensitive to light and moisture. It avoids bright light and dry soil.

Nutrition: Earthworm feeds on organic debris found in the soil. It hunts at night and feeds on fallen leaves etc. in the soil. It

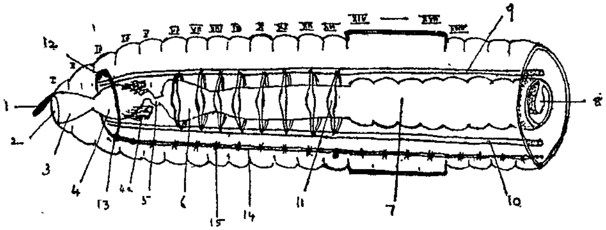

Fig. 65

Earthworm. Side view showing digestive, circulatory and nervous systems.

1. Prostomium 2. Mouth 3. Buccal cavity 4. Pharynx
4A. Pharyngeal glands 5. Oesophagus 6. Gizzard 7. Intestine
8. Typhlosole 9. Dorsal blood vessel 10. Ventral blood vessel
11. Lateral heart 12. Brain 13. Sub pharyngeal ganglia
14. Double ventral nerve cord 15. Segmental ganglia

takes the soil along with the organic matter into its body and digests the useful material. The alimentary canal starts from the mouth in the centre of the first segment.

The mouth leads into a buccal cavity inside segments 1 and 2 This is connected to a muscular pharynx inside segments 3 and 4. The pharynx can be everted and is useful to draw in soil with food. The pharynx is surrounded by pharyngeal glands which produce digestive enzymes. The pharynx is followed by a short narrow oesophagus inside segment number 5. This joins a hard gizzard. Gizzard is conical and is inside segments 6 and 7. The soil together with organic matter is ground into a fine powder inside the gizzard. The gizzard is followed by a long intestine which extends upto the anus in the last segment. The intestine is bulged in every segment from the 14th segment onwards. That is why it is called sacculated intestine. There is a vertical fold of tissue hanging into the cavity of the intestine from the dorsal wall. This extends throughout the length of the intestine. This structure is called the **Typhlosole.** This helps to increase the area of absorption of the intestine. Digestive glands may also be present on the intestinal wall. The digested food is absorbed by the blood on the wall of the intestine and the undigested mud comes out of the anus. The worm piles up this soft mud at the entrance to its burrow. These are called worm casts. The food moves through the alimentary canal by peristaltic movements caused by muscles on the wall of the alimentary canal.

Circulatory System: In earthworm there is a definite circulatory system. Blood circulates inside closed blood vessels and capillaries. So it is called a closed vascular system. The blood is red in colour due to the pigment haemoglobin dissolved in the plasma.

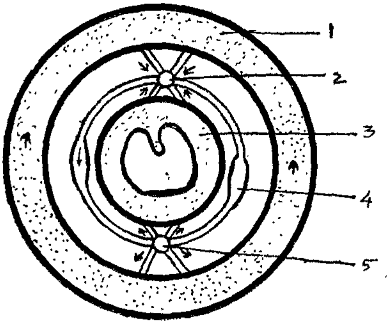

Fig. 66
Earthworm C.S. showing circulation
1. Body wall 2. Dorsal blood vessel
3. Intestine 4. Lateral heart
5. Ventral blood vessel

There are two longitudinal blood vessels, one above the intestine called the dorsal blood vessel, and another

below the intestine called the ventral blood vessel. The dorsal vessel is the collecting vessel and it has valves inside. It has a muscular wall which propels blood forwards. The ventral vessel is a distributing vessel and it has no valves inside and it is non contractile. The dorsal vessel and the ventral vessel are connected by 8 pairs of lateral hearts in segments 6 to 13 one pair in each segment. These are also valvular and contractile and push the blood from the dorsal vessel to the ventral vessel. Blood flows in the dorsal vessel from behind forwards and in the reverse direction in the ventral vessel. In every segment the ventral vessel supplies blood to the body wall by a pair of smaller vessels. The blood is oxygenated in the skin and is collected back by the dorsal vessel. Similarly a pair of small vessels supply blood to the intestine from the ventral vessel. After absorption of food this blood reaches the dorsal vessel by a pair of vessels. In segments where there are excretory organs or nephridia blood is supplied to them from the ventral vessel and is collected back after purification by the dorsal vessel.

Respiration: Earthworm respires with the help of its skin. So it is called cutaneous respiration. Skin is always kept moist by secretions of glandular cells of the epidermis. Besides, the body fluid oozes out, through the dorsal pores (dorsally one in every intersegmental groove behind 10th segment) to keep the skin moist. Blood is supplied to the skin from the ventral vessel. The diffusion of gases takes place in the skin. The oxygenated blood is collected by the dorsal blood vessel.

Excretion: Excretion is a process of removing the metabolic waste products. In earthworm excretion is effected by a series of paired minute tubes called Nephridia. These are present in almost all segments except a few. A typical nephridium is a long coiled convoluted minute tube, connecting the body cavity or coelom to the exterior. The inner opening of the tube is funnel like and ciliated. This is called the nephrostome. This is continued by a narrow tube to the next segment through the septum. There it joins a broader convoluted region of the tube. This in its turn joins another narrow part which opens outside by the nephridiopore. The first part of the tube immediately after the funnel is called ciliated region as its inner wall has cilia. The middle broader part is called glandular

region because it has glands on its wall. The third part is called muscular region. The waste is collected from the body cavity by the funnel like nephrostome. More is added by the glands on the wall of the middle glandular region and all the waste is sent out through the nephridiopore.

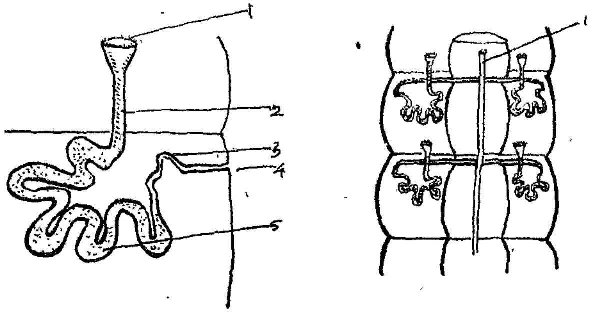

Fig. 67

Earthworm Typical nephridium

1. Nephrostome 2. Ciliated region 3. Muscular region

4 Nephridiopore 5. Glandular region

Meganephridia

1. *Supra intestinal* excretory canal

The Megascolex has a slightly modified pattern of excretion. Here also nephridia are present. There are three types of nephidia in Megascolex namely 1. Meganephridia. 2. Micronephridia and 3. Pharyngeal nephridia.

Meganephridia: These are present, one pair in each segment from the 19th segment onwards. Each meganephridium has a ciliated funnel like nephrostome, a ciliated region, a glandular region and a muscular region. But the last part does not open to the outside. Instead it is carried on the back of the septal walls as the septal excretory canal and opens into a longitudinal canal above the intestine. This is called the supra intestinal excretory canal and lies inbetween the dorsal blood vessel and the intestine. This canal opens into the alimentary canal by a pair of openings in every segment and the waste finally goes out through the anus.

Micronephridia: These are present in the clitellar region. These are like the typical nephridia but do not have the internal funnel like nephrostome and the ciliated region. Their inner ends are blind. These open to the outside on the skin by nephri-

diopores. The glandular part collects the waste which is sent outside. As these open out on the skin, these are also called integumental nephridia.

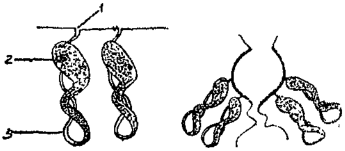

Fig. 68
Micronephridia, Pharyngeal nephridia
1. Nephridiopore 2. Glandular region
3. Muscular region

Pharyngeal Nephridia: These occur around the region of the pharynx. These are structurally similar to the micronephridia as these also lack the nephrostome and the ciliated region. These open into the pharynx.

Cholorogogen cells: These are special cells found on the outer wall of the intestine. These cells collect waste materials and when they are fully laden, drop into the body cavity. Then these are removed by the nephridia.

Nervous System: The nervous system of the earthworm consists of two sets of paired ganglia around the pharynx and one ganglion in each segment. Above the pharynx, there is a pair of ganglia called the supra pharyngeal ganglia or the brain.. These are connected to another pair of ganglia below the pharynx called the sub-pharyngeal ganglia. The connection around the pharynx is known as circum pharyngeal nerve ring. Two long nerve cords arise from the sub pharyngeal ganglia and run ventrally to the ventral blood vessel to the last segment. In every segment the two nerve cords are joined to a segmental ganglion from which nerves are given off to the organs of the

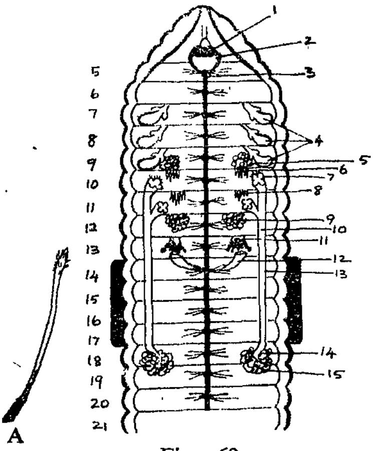

Fig. 69
Earthworm Nervous & Reproductive systems
1. Brain 2. Circumpharyngeal connective
3. Sub pharyngeal ganglia 4. Spermathecea
5, 9. Seminal vesicle 6,8. Testis 7. Ciliated funnel 10, 13. Vas deferens
11. Ovary 12. Oviduct 14. 15: Prostate glands A. Penial seta

segment. There are no sense organs except the light sensitive and touch sensitive cells of the epidermis.

Reproduction: Earth worm is a hermaphrodite (*i.e.*) it has both the male and the female reproductive organs in the same individual. All the reproductive organs are placed within the anterior 18 segments.

The male part of the system consists of 2 pairs of testes. These are attached to the anterior septum of the 10th and 11th segments–one pair in each segment. Testes produce the male sex cells or sperms. There are two pairs of seminal vesicles one pair in the 9th segment and another in the 12th segment. Sperms undergo further development in these seminal vesicles. There are two pairs of ciliated funnels or ciliary rosettes in segments 10 and 11 which collect the mature sperms. The cilitated funnels of the same side are connected to a long narrow tube called the vas deferens. The 2 vasa defeientia of the 2 sides proceed backwards up to the 18th segment where they join a pair of prostate glands. Here the sperms are bundled and are made ready to be transferred to another worm. Embedded in the prostate glands are a few long chitinous rod like setae called penial setae which help in transferring the sperms to another worm. The male openings are on the ventral side of the 18th segment.

The female part of the system consists of a pair of ovaries. These appear as bunches of grapes and are attached to the anterior septum of the 13th segment. Two short tubes or oviducts carry the mature ova to the outside opening ventrally on the 14th segment. Three pairs of sac like spermathecae (sperm receiving bags) are found in the 7th, 8th and 9th segments, one pair in each segment. Each spermatheca has a central bag like structure called ampulla and 2 short side branches called diverticulae. The spermathecae open to the outside ventrally by paired openings at the intersegmental grooves between segments 6 and 7, 7 and 8, and 8 and 9.

Though the worm is a hermaphrodite, 2 worms are necessary for reproduction. Two worms from adjacent burrows come out and apply themselves by their ventral surfaces from opposite directions so that the male openings of one are opposite the spermathecal openings of another. With the help of penial setae

the sperms of one worm are transferred and filled in the spermathecae of the other worm. After this mutual transfer the worms separate. The coming together of two worms for this sperm transfer is called copulation.

Now the clitellum of the worm becomes thicker and loose. The mature ova are deposited on the inner wall of the clitellar ring. Then the worm wriggles out backwards pushing the clitellar ring forwards. When the clitellar ring comes opposite the spermathecal openings, sperms already stored there are shed and fertilisation takes place. Finally the ends of the clitellar ring are closed and the ring becomes a closed cocoon containing eggs. This cocoon is deposited in the soil. The young worms develop inside the cocoon and when fully formed come out and live on their own.

CHAPTER VIII

Perplaneta americana

(COCKROACH)

The cockroach is a pest occurring in the dark corners and storerooms. This is a nocturnal insect hunting for its food at night. It is placed in classification as follows:

Kingdom	—	Animalia
Sub kingdom	—	Invertebrata
Phylum	—	Arthropoda
Class	—	Insecta (Hexapoda)
Order	—	Orthoptera
Family	—	Blattidae
Genus	—	Periplaneta
Species	—	americana

The body of the animal is divisible into distinct regions namely the head, neck, thorax and abdomen.

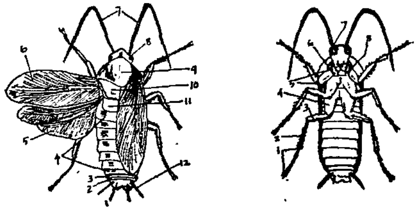

Fig. 70

Cockroach A. Dorsal view B. Ventral view 1. Anal styles 2, 3, 8, 9. Segments 4. Abdomen 5. Hindwing 6. Forewing 7. Antennae 8 Eye 9. Prothorax 10. Mesothorax 11. Metathorax 12. Anal cerci

1. Tarsus 2. Tibia 3. Femur 4. Coxa 5. Trochanter 6. Maxillae 7. Eye 8. Labial palps

The head is pear shaped and it is held at right angles to the axis of the body. It is covered by hard chitinous plates. There are two large compound eyes on the dorsal side of the head. Each compound eye is made of numerous units called **ommatidia.** So the cockroach has an efficient mosaic image of its objects. There are two long annulated whip like structures arising from the head. These are called **antennae** which are used as feelers. Near the base of the antennae there are two

soft white spots called **fenestrae** which are useful to find differences in temperature. The two plates covering the head on top, between the eyes, are called **epicranial plates.** The front of the head has a broad central plate called **Clypeus.** The sides of the head are covered by two plates called **genae.** The upper lip or **labrum** hangs in front. There are various organs in the lower part of the head constituting the mouh parts.

The neck is a narrow cylindrical part supported by several ring like thickenings made of chitin. These are called the **cervical sclerites.**

The thorax is made of three segments, namely Prothorax, Mesothorax and Metathorax. Each segment has a dorsal plate, called **tergum,** a ventral plate called **sternum** and at the sides a membranous **pleura.** The thorax bears two pairs of wings dorsally and three pairs of legs ventrally. The first pair of wings or forewings are on the mesothorax. These are not useful for flight but serve to cover the hindwings and the abdomen. So these are also called **tegmina** or **elytra.** The second pair of wings or hindwings are on the metathorax and they are membranous. These are used in flight.

Each segment of the thorax bears ventrally one pair of legs. The legs are made of many joints. (Hence the name Arthropoda) Each leg has the following joints namely **coxa, trochanter, femur, tibia** and a terminal five segmented **tarsus.** The last segment of the tarsus bears a pair of claws and a soft pad called **pulvillus.** The tibia and tarsus bear many stiff bristles.

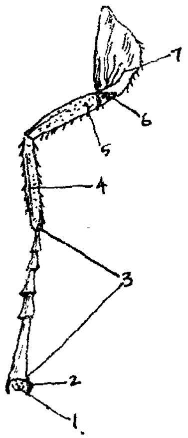

Fig. 71

Cockroach leg

1. Pulvillus 2. Claw 3. Tarsus 4. Tibia 5. Femur 6. Trochanter 7. Coxa

The abdomen of the cockroach has ten segments. Each segment has a dorsal plate called tergum and a ventral plate called sternum. At the sides, there are pleural membranes. The last segment bears a pair of annulated projections called **anal cerci.** In the males, there is an additional pair of projections called **anal styles.** These are absent in the females. The abdomen is broader in the females and narrower in males. The sternum of the seventh segment in the abdomen is cleft in the female but it is entire in the male.

Nutrition: Cockroach hunts for its food in darkness. It eats almost anything. It takes for its food vegetables, meat, paper, leather, cloth, etc. So it is called an omnivorous insect. It has in its mouth a number of oragns which help to cut and chew the food. The various organs in its mouth are (1) **Labrum** or upperlip (2) **Labium** or lowerlip (3) Hypo-pharynx or tongue (4) a pair of jaws or **Mandibles** and (5) a pair of finger like **Maxillae.**

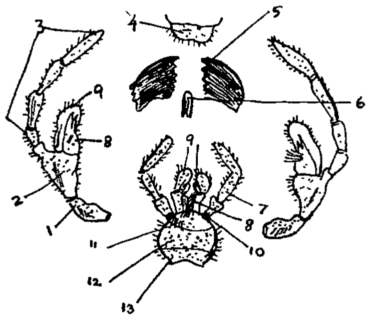

Fig. 72

Mouth parts of Cockroach.

1. Cardo 2. Stipes 3. Maxillary palp 4. Labrum 5. Mandibles 6. Tongue 7. Labial palp 8. Lacinia 9. Galea 10. Palpiger 11. Prementum 12. Mentum 13. Submentum

The labrum is flap like. The tongue is small and somewhat cylindrical. The two mandibles are very hard and have toothed inner edges. These work sideways and cut the food into pieces. The maxillae are found one on either side. Each maxilla has a basal part made of two segments namely **cardo** and **stipes.** The stipes bears at its free end, two blade like structures by name **galea** and **lacinia** and a five jointed long projection called the **maxillary palp.** The maxillae are referred to as first maxillae and the labium similar to these is called the second Maxilla.

The labium or lower lip is also called as second maxilla. It has a plate like part made of three segments, namely **prementum, mentum,** and **submentum.** The prementum carries two pairs of blade like structures. The inner pair is formed by **lacinia** or **glossae** and the outer pair by **galea** or **paraglossae.** The mentum carries on either side a three jointed projection called **labial palp.** The labial palp arises from a small segment called **palpiger** on the mentum. The labial palps and the maxillary palps hold the prey. The blade like galea and lacinia cut the food and the mandibles also cut and chew the food.

Alimentary canal: This is a long tubular structure divisible into three parts namely (1) foregut (2) midgut and (3) hindgut. The foregut is formed by the **oesophagus, crop** and the **gizzard.**

The oesophagus is a narrow tube starting from the mouth. It gradually enlarges into a sac like part called the crop. Below the crop, is a pear shaped gizzard. The gizzard contains six plate like hard chitinous structures, which pulverise the food. The midgut or mesenteron is a narrow tube, where digested food is absorbed. The hindgut has three parts namely **ileum, colon** and **rectum.** The rectum opens out at the anus.

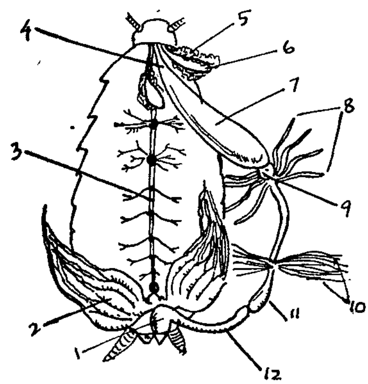

Fig. 73-A

Cockroach-viscera

1. Rectum 2. Ovary 3. Nerve cord 4. Oesophagus 5. Salivary gland 6. Salivary receptacle 7. Crop 8. Hepatic Caeca 9. Gizzard 10. Malpighian tubules 11. Ileum 12. Colon

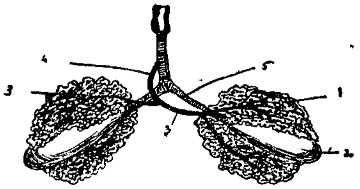

Fig. 73-B

Salivary Apparatus

1. Salivary gland 2. Salivary receptacle 3. Salivary duct 4. Common salivary duct 5. Receptacular duct

There are two sets of glands connected with digestion. They are (1) the salivary glands and (2) the hepatic caecae. There are four salivary glands two on either side of the oesophagus. The salivary glands secrete saliva. This is collected by salivary ducts. The two ducts from the same side join together and then combines with its fellow from the other side to form a single common salivary duct. On either side of the oesophagus, there is a bag like salivary receptacle to store the saliva. A duct called receptacular duct arises from each receptacle. The two receptacular ducts join together to form a common receptacular duct. The entire arrangement is spoken of as the salivary apparatus. The saliva continues its action on food even inside the crop. Saliva has enzymes to digest the carbohydrate parts of the food.

The hepatic caecae are eight blind tube like structures attached at the junction of the gizzard with the mesenteron,

These secrete the hepatic juice, which has enzymes to digest the fats and proteins of the food.

The digested food is absorbed into the blood through the wall of the mesenteron. The undigested food is passed on through ileum colon and rectum. It is finally sent out through the anus.

Malpighian tubules: In cockroach, there are numerous fine yellow tubules attached at the junction of the mesenteron with the hindgut. These fine tubules float in the blood. These tubules collect the metabolic waste from the blood. This waste is passed on into the hindgut to be sent out by anus. So the Malpighian tubules, as they are called, act as excretory organs of cockroach.

Circulation: Cockroach has an open type of blood vascular system (*i.e.*) Blood is not contained inside blood vessels. The whole body cavity of the cockroach is filled with blood. Such a body cavity filled with blood is known as a **Haemocoel.** The blood of

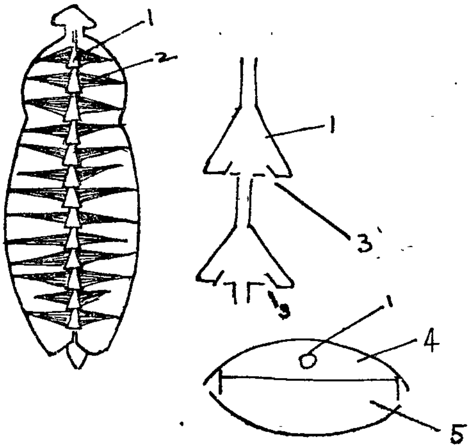

Fig. 74

Cockroach. Circulatory system

1. Heart 2. Alary muscles 3. Ostia 4. Pericardial chamber 5. Peri visceral chamber

the cockroach is colourless. It has no respiratory pigment, because blood has no work in connection with transport of Oxygen. The blood is also known as **haemolymph.**

The body cavity of the cockroach is divided into a dorsal and a ventral chamber by a horizontal partition called the pericardial membrane. This membrane has many valvular openings which permit blood to go from the ventral chamber to the dorsal chamber, but not backwards. The ventral chamber is called the perivisceral chamber, as it contains the viscera. All the organs of the viscera are bathed in the blood. The dorsal chamber is called the pericardial chamber as it contains the heart.

The heart of the cockroach is like a long tube lying mid-dorsally in the pericardial chamber. It is divided into thirteen chambers. Each chamber is like a funnel, with the stem pointing forwards. All the chambers are linked like a telescope. There are two small holes in each chamber posteriorly, guarded by valves. These holes are called ostia. Blood enters the heart through these ostia and flows towards the head.

The heart of the cockroach is not made of muscles. So it cannot contract and relax. Each chamber of the heart is attached with a pair of muscles at the sides, called the **alary muscles.** These muscles make the heart pump the blood.

The blood flows into the head from the heart. From the head the blood oozes back into the perivisceral chamber. Then it goes up to the pericardial chamber and then into the heart.

Respiration: Cockroach has an efficient method of respiration. The atmospheric air is made to come in contact with all tissues of the body directly, by a system of branching tubes called the **Tracheal system.** The blood has no work in connection with respiration. There are ten pairs of holes called **spiracles** or **stigmata** at the sides of the body. These are found in the pleural membranes. There are two pairs of spiracles in the thorax, one pair in the mesothorax and another pair in the metathorax; The other eight pairs of spiracles are in the first eight abdominal segments one pair in each. These spiracles can be closed at will by valves.

The spiracles join a longitudinal tube on either side, called the **trachea.** These tracheae are interconnected at intervals by branches. Numerous small tubes called **tracheoles** arise from the tracheae. These branch again and again to reach all tissues. The tracheae and tracheoles are always kept open, by a spiral

thickening of their walls. This thickening is by a material called the chitin. Air goes through these tracheae and tracheoles and reaches all tissues giving out its oxygen. In return it collects the CO_2 from the tissues and comes out. The entry of air and exit of the same, is brought about by the movements of the body wall, helped by muscles.

Nervous System: The brain of the cockroach is formed by a pair of ganglia, placed above the oesophagus and beneath the epicranial plates. These ganglia are therefore called the supra oesophageal ganglia. Beneath the oesophagus, there is another pair of ganglia, known as the sub-oesophageal ganglia. These are connected with the brain by circum-oesophageal connectives coming round the oesophagus. The brain supplies nerves to the antennae and the eyes. The suboesophageal ganglia supplies nerves to the mouth parts.

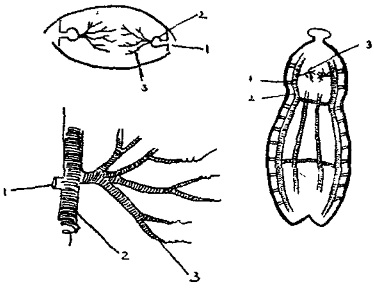

Fig. 75
Cockroach-Respiratory system
1. Spiracle 2. Trachea 3. Tracheoles

Arising from the sub-oesophageal ganglia, are two nerves which run in the mid-ventral line of the body. These constitute the double ventral nerve cord. In the thorax, there are three thoracic ganglia on the ventral nerve cord which supply nerves to the organs of the respective segments. In the abdomen there are only six abdominal ganglia. The sixth one is bigger and it supplies nerves to the organs of the sixth and subsequent segments.

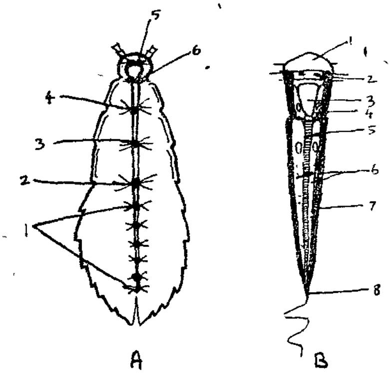

Fig. 76-A 76-B
A. Nervous System
1. Abdominal ganglia
2,3,4. Thoracic ganglia 5. Brain
6. Sub oesophageal ganglia
B. Ommatidium
1. Cornea 2. Corneagen cell
3. Crystalline cone 4. Vitrellae
5. Rhabdome 6. Rhabdomeres
7. Pigment 8. Nerve

The compound eye of the cockroach is made up of numerous units called **ommatidia.** Each ommatidium is like an independent eye. It has a transparent cornea at the top. Below the cornea is the corneagen cell. Behind it, is the lens called the crystalline cone. Surrounding the lens are four long cells called **Vitrellae,** which produce the lens. Underneath the lens, is a refractive body called the **Rhabdome** or screen. Four cells, called **Rhabdomeres** surround the Rhabdome. The Rhabdome is connected with the brain by a nerve. The compound eye is very efficient as it produces a mosaic image with the help of numerous ommatidia.

Reproduction: Sexes are separate. The male cockroach can be identified by the narrow abdomen and by the presence of a pair of projections called anal styles, at the hind end. Besides, all the sternal plates of the abdomen in the male are entire. In the female, anal styles are absent. The abdomen is broad and its seventh sternum is cleft in the centre.

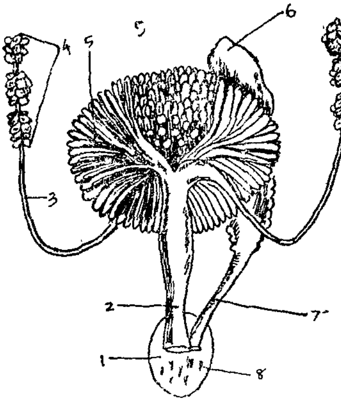

Fig. 77-A

Cockroach. Male reproductive system

1. Genital pouch 2. Ejaculatory duct
3. Vas deferens 4. Testes
5. Mush room shaped gland
6. Conglobate gland 7. Duct of conglobate gland 8. Gonapophyses

Male :

The reproductive organs of the male are the testes. These appear in three groups on either side. Each group looks like a mass of small globular bodies. The testes produce the sperms. These are collected by a narrow tube on either side, called the vas deferens. The two vasa deferentia proceed backwards and meet in the centre to form a seminal vesicle. The seminal vesicle gives rise to a number of short and long branches. All these make the seminal vesicle look like a mushroom. So it is called the mushroom-shaped gland. A short tube called ejaculatory duct connects the

mushroom shaped gland to the genital pouch. In the genital pouch there are chitinous processes known as gonapophyses, which help in the transfer of sperms from the male to the female. There is a sac like organ called the conglobate gland, also attached to the genital pouch. This produces a secretion to form the cover for spermatophores (sperm bundles).

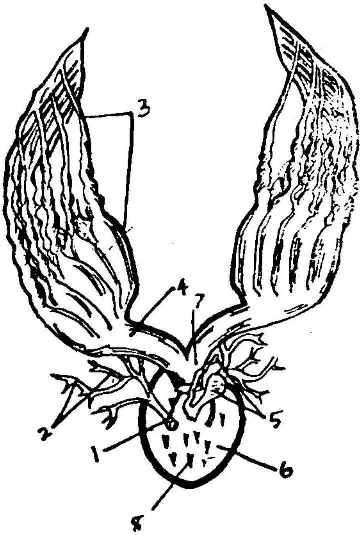

Fig. 77-B

Cockroach-Female reproductive system

1. Vulva 2. Colleterial glands
3. Ovary 4. Oviduct
5. Spermatheca 6. Genital pouch
7. Uterus 8. Gonapophyses

Female :

In the female, there are two ovaries. Each ovary consists of eight ovarian tubules. The anterior ends of these tubules are filamentous. Posteriorly all the eight ovarian tubules of an ovary, join a short tube, the oviduct. The two oviducts from the two ovaries meet in a central sac like uterus, which opens into the genital pouch. This opening is called the Vulva. The genital pouch contains chitinous projections called gonapophyses, which help in egg laying. There is a small sac like spermatheca attached to the genital pouch. This receives sperm bundles from the male, during copulation, and stores them. A pair of much branched glands called colleterial glands open into the genital pouch. These secrete the material for the egg case or ootheca.

Life history: At a time each ovary produces eight eggs. So the sixteen eggs from the two ovaries reach the uterus through the oviducts. During the copulation, the spermatheca of the female receives the sperms. When the eggs come out, into the genital pouch, the sperms already stored in the spermatheca are released and fertilisation takes place. All the sixteen fertilised eggs are

arranged in two rows of eight each. Then the colleterial glands secrete a material which hardens and forms an egg case. This hard brown structure containing sixteen eggs is also called the ootheca. The female cockroach carries the egg case and deposits it in a safe dark place.

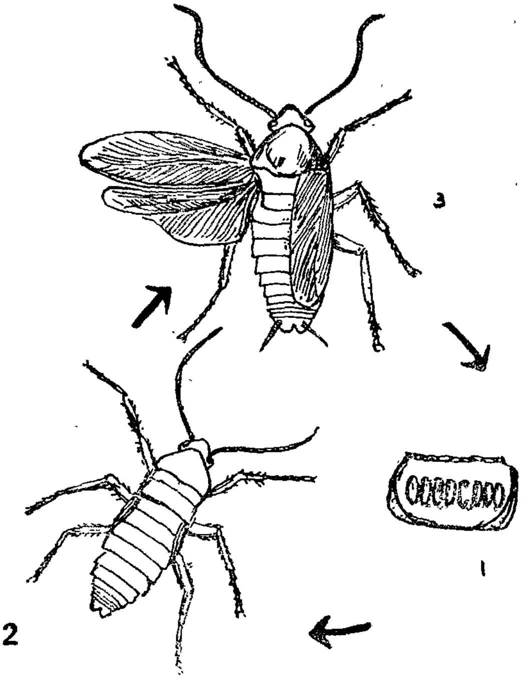

Fig. 78
Life cycle. 1. Egg case 2. Nymph 3. Adult

After a couple of weeks, the eggs hatch and small cockroaches come out. These young ones are white in colour and they do not have wings and reproductive organs. Such young ones are called **Nymphs**. The nymph grows in size for sometime and the body wall becomes hard and brown in colour. Further growth is not possible. So the young one develops another soft white wall inside, and casts off the old body wall. This process is called **moulting** or **ecdysis**. The cockroach moults seven times. The period between two successive moults is called an instar. After the seventh moult, wings and gonads develop and cockroach becomes an adult. The life history shows, therefore, an incomplete orpartial metamorphosis.

CHAPTER IX

Lamellidens lamellidens

(Fresh-water mussel)

This animal is popularly called the clam. This is a 'soft bodied' animal found living at the muddy or sandy bottoms of rivers, lakes and ponds. In classification it is placed as follows:

Kingdom	—	Animalia
Sub kingdom	—	Invertebrata
Phylum	—	Mollusca
Class	—	Pelecypoda
Order	—	Eulamellibranchiata
Family	—	Unionidae
Genus	—	Lamellidens
Species	—	lamellidens

Structure: The animal is laterally compressed with a muscular projection called the foot extending ventrally. The body is enclosed by a shell made up of two pieces or valves, lateral in position, which are attached dorsally by a hinge ligament. The two shell valves are articulated with the help of hinge teeth and sockets. Each shell valve has an elevated conical part called 'umbo'. Many concentric lines of growth can be seen externally.

The shell is made of calcium carbonate secreted by the mantle which is like a fold of skin covering the animal. The shell has three distinct layers namely (1) an external periostracum, brownish in colour, made up of a horny material called conchiolin (2) a middle prismatic layer made up of vertical layers of $CaCO_8$ separated by thin layers of conchiolin and (3) a lower nacreous or 'mother of pearl' layer formed by very thin horizontal layers of $CaCO_8$. This layer is iridiscent (i.e.) it scatters light in different hues. If a foreign body gets in between this layer and the mantle, the nacreous layer is formed around the body creating a pearl.

There is no head. This want of cephalisation is due to the sedantary mode of life. The mouth is anterior and it is flanked

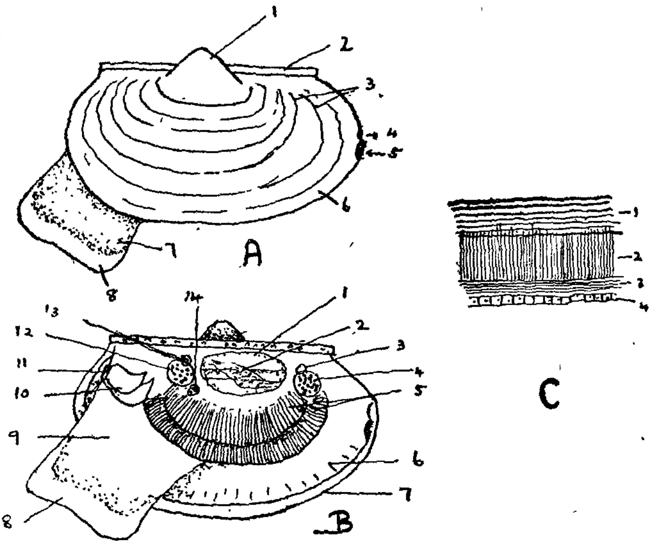

Fig. 79

79-A External features

1. Umbo 2. Hinge 3. Lines of Growth 4. Exhalent siphon 5. Inhalent siphon 6. Shell 7. Visceral mass 8. Foot

79-B Animal exposed. 1. Pericardium 2. Heart 3. Posterior retractor muscle 4. Posteriot adductor muscle 5. Gills 6. Mantle 7. Shell 8. Foot 9. Visceral mass 10. Labial palps 11. Mouth 12. Anterior adductor muscle 13 Anterior retractor muscle 14 Protractor muscle

79-C L. S. Shell. 1. Periostracum 2. Prismatic layer 3. Nacreous layer 4 Mantle

on either side by two pairs of flap like labial palps. The pericardium is dorsal. On either side of the animal, there are two leaf like gills or ctenidia. At the hind end of the animal there are two openings formed by the approximation of the mantle edges. The lower aperture is called inhalent siphon through which water is drawn into the mantle cavity. This aperture has small tentacular processes which prevent hard particles of sand getting inside. The upperhole is called the exhalent siphon through which water comes out. Ventrally a muscular organ called the foot can be seen extending in front.

The two shell valves are kept tightly shut together by sets of muscles extending between them. Antero-dorsally there is a strong muscle known as anterior adductor muscle. Similar to this there is another muscle postero-dorsally called the posterior adductor muscle. Anteriorly and posteriorly there are two retractor muscles one close to each adductor muscle. There is also a small protractor muscle behind the anterior adductor muscle.

Locomotion: Movement of the animal is very slow. This movement is brought about by the muscular foot. The foot is a fleshy muscular organ seen projecting in between the two shell valves anteriorly. First the foot is extended and its tip gets dilated a little to anchor it in mud. Then the foot is contracted drawing the animal a little forward during the process. This action is repeated. The movement appears like ploughing through the mud. The movement is erratic and not in a straight line.

Nutrition: The animal feeds on small micro organisms that come along with the current of water that is swept in through the inhalent siphon. The surface of the two pairs of gills or ctenidia is ciliated. The cilia create a current of water to flow inwards through the inhalent siphon. The surface of the gills contain mucous glands which secrete a sticky mucus. Small organisms get caught in the mucus. The mucus band on either side is moved forwards, like conveyor belts by the action of the cilia. These bands are directed into the mouth with the help of the labial palps. This ciliary mode of feeding is considered to be primitive or else it could be due to degenerate habits of the animal as a secondary adaptation.

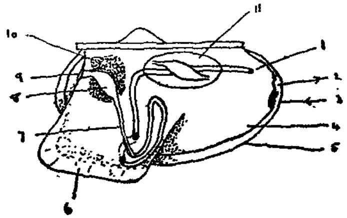

Fig. 80
Digestive System
1. Anus 2. Exhalent siphon
3. Inhalent siphon 4. Mantle 5 Shell
6. Foot 7. Intestine 8. Stomach
9. Mouth 10. Digestive gland
11. Pericardium

The mouth leads into a short oesophagus which joins the stomach. The stomach is surrounded by a large mass of digestive gland known as hepatopan creas. The digestive enzymes enter the stomach as a solid style called the crystalline style. As and when required this style is dissolved and made use of. The stomach is continued as a narrow tube, the intestine. This is long and forms a loop in the

visceral mass and then enters the pericardium as the rectum. It pierces the ventricle and passes through it and reaches the exhalent siphon.

Respiration:

The animal lives in water and therefore makes use of the oxygen dissolved in the water. There are two gills or ctenidia one on either side of the body enclosed inside the mantle. They hang down in the mantle cavity. Each gill is like a plate bent upon itself. This folded structure is called a lamina. Each lamina has two sides or walls called lamellae. The two lamellae of a lamina, are fused in front,below and behind to form a trough like structure. The space enclosed between two lamellae of a lamina, is called interlamellar space. This is not continuous, but is partitioned by many cross walls called inter lamellar junctions. These junctions contain blood spaces where blood is oxygenated. Because of these junctions, the interlamellar space is divided into many compartments or water tubes. Rows of small holes called ostia are present at the sides of the lamellae, through which water enters the water tubes. The lamellae are

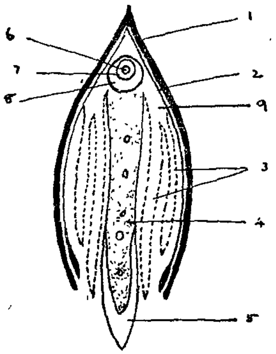

Fig. 81-A

T.S. of Lamellidens
1. Shell 2. Mantle 3. Gills 4. Visceral mass 5. Foot 6. Rectum 7. Heart 8. Pericardium 9. Epibranchial space

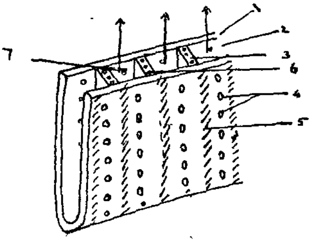

Fig. 81-B

A Gill lamina

1. Lamella 2. Interlamellar space 3. Interlamellar junction 4. Ostia 5. Cilia 6. Blood spaces 7. Water tube

formed by numerous gill filaments joined closely as a layer. Their junctions are called inter filamentor junctions. The ostia

are present in between the gill filaments. Above the gills on each side, is a space called the epibranchial space into which all water tubes open. The epibranchial spaces of the two sides meet and open at the exhalent siphon behind.

Water is drawn into the mantle cavity by ciliary action of the cilia on the surface of the gills. The water enters through the inhalent siphon and then it enters the water tubes of the laminae through the ostia. Blood is oxygenated in the interlamellar junctions. After oxygenation of blood, the water goes up to the epibranchial spaces and then is sent out through the exhalent siphon.

Circulation: The circulatory system is mainly of the open type. There is a heart made of one ventricle and two auricles. The heart is placed inside the pericardium, which is dorsally placed. The two auricles are on the two sides of the ventricle. The ventricle gives rise to an anterior aorta and a posterior aorta through which blood reaches all blood spaces or sinuses of the body. Blood is given to the visceral mass, the foot and the mantle. This blood is returned to the kidneys and then sent to the gills. From the gills blood is sent up to the auricles and thence to the ventricle. The blood is almost colourless but a faint haemocyanin pigment can be seen which helps to transport oxygen.

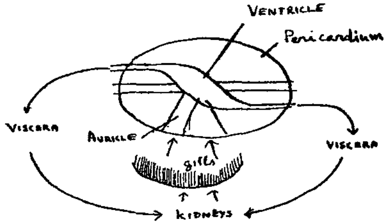

Fig. 82
Circulation

Excretion: Removal of waste is carried on by a pair of kidneys called the organs of Bojanus. These are placed beneath the peiicardium one on either side. Each kidney is like a long tube bent on itself. One end opens inside the pericardium and the other end opens inside the mantle cavity.

Near the pericardial opening there are numerous glands called Keber's glands which extract

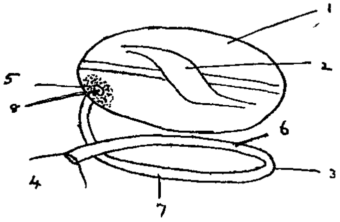

Fig. 83
Excretion
1. Pericardium 2. Heart 3. Kidney
4. Mantle cavity 5. Keber's gland
6. Non glandular part of kidneys
7. Glandular part of kidney
8. Reno pericardial opening

waste from the blood and pass them on into the kidneys. The waste is discharged into the mantle cavity from where it is moved through the exhalent siphon.

Nervous system: The nervous system consists of paired ganglia and their connectives. There are three pairs of ganglia namely (1) cerebral ganglia (2) pedal ganglia and (3) visceral ganglia. The cerebral ganglia are placed above the oesophagus one on either side. They are connected across dorsally by the cerebral commissure.

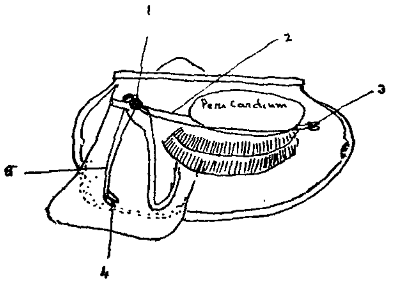

Fig. 84

Nervous system

1. Brain or cerebral ganglia 2. Cerebro visceral connective 3. Visceral ganglia 4. Pedal ganglia 5. Cerebro-pedal connective

Just above the foot, there is a pair of pedal ganglia which supply nerves to the foot. The pedal ganglia are connected to the cerebral ganglia by a pair of nerves called the cerebro-pedal connectives. There is a pair of visceral ganglia behind and below the pericardium at the posterior end. These are also connected to the cerebral ganglia by two long cerebrovisceral connectives, running one on either side of the pericardium.

Reproduction: The sexes are separate. A pair of gonads appear at the sides of the visceral mass amongst the coils of the intestine, each as a bunch of branched tubes. Each gonad has a short duct which opens into the mantle cavity by the genital aperture, in front of the renal opening. The gametes are released into the mantle cavity where fertilisation takes place.

The egg develops into a larva called the Glochidium larva. This larva is an independent free swimming larva. It has two shell valves which are attached dorsally by a hinge. There is a strong adductor muscle which helps in flapping movements of the shell-during swimming. The shell valves are lined internally by a sensitive mantle with sensory papillae. Each shell valve has a strong

and sharp spine at the tip. There is a byssus gland which secretes a long adhesive thread or byssus.

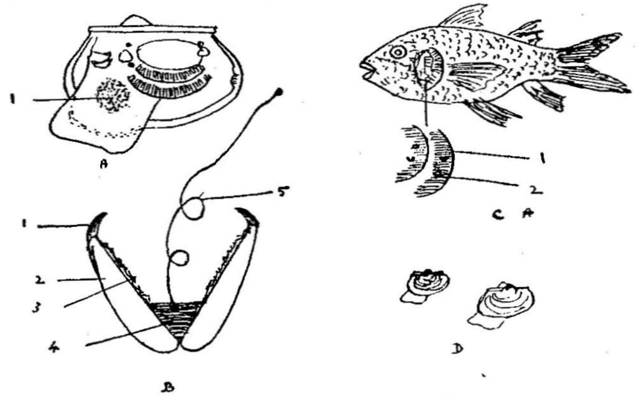

Fig. 85-A Fig. 85-B

Reproduction

A. 1. Gonad
B. Glochidium 1. Spine 2. Shell 3. Mantle 4. Adductor muscle 5. Byssus
C. Teleost fish (host) 1. Gill 2. Glochidia
D. Young mussel

The larvae swim about in search of a host which is usually a fresh-water teleost fish. The larvae get attached to the tender skin of the gills of the fish and then bite into the skin of the fish with the help of sharp spines of the shell. The skin of the fish grows over the larva making it internal. Inside the skin of the fish, the larva metamorphoses to become an adult. By the time, the metamorphosis is complete, the skin of the fish ruptures liberating young mussels into the water.

The parasitic existence of the glochidium larva on the fish bestows three advantages.

1. The larva is protected from enemies.
2. The larva is nourished by the fish.
3. The fish being a fast swimmer helps in dispersing the mussels to great distances.

CHAPTER X

Asterias rubens

(Star fish)

The star fishes are entirely marine. They get their popular name 'starfishes' by their shape, which resembles the conventional representation of the star. The star fish is placed according to classification as follows:

Kingdom	—	Animalia
Sub kingdom	—	Invertebrata
Phylum	—	Echinodermata
Class	—	Asteroidea
Order	—	Forcipulata
Family	—	Asteridae
Genus	—	Asterias
Species	—	rubens

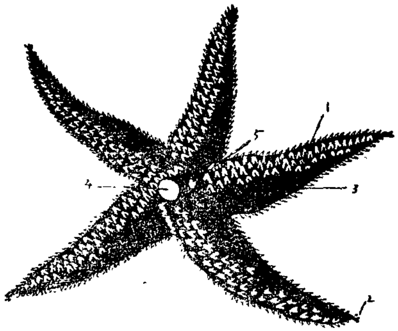

Fig. 86-A

Star fish Dorsal view

1 Spines
2. Tentacles
3. Arm
4. Madreporite
5. Anus

The star fishes are found in shallow waters as well as in deep seas. They are more common where rocky bottoms are present or wherever oyster beds are seen.

Structure: The body consists of a central disc from which five or some times more arms radiate. Thus they exhibit radial symmetry. The ventral or oral surface is almost flat while the dorsal or aboral surface is more convex. The starfishes are generally coloured cream, yellow or orange.

The oral surface possesses a centrally placed small mouth. Five narrow grooves run from the mouth, radially along the ventral surface of the arms. These are called ambulacral grooves. On either side of the grooves very small finger like, delicate projections are seen. These are the tube feet which help in locomotion and feeding. The tips of the arms have a small tentacle each with a bright light sensitive eye spot.

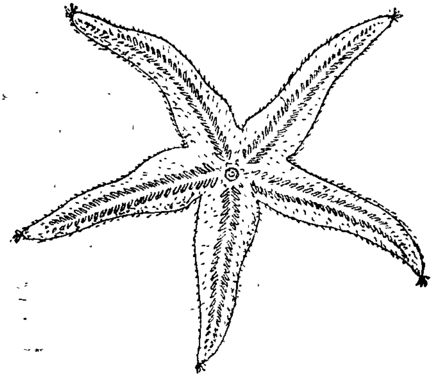

Fig. 86-B
Star fish. Ventral View

The aboral surface has many structures. There is a small central opening on the dorsal surface of the disc. This is the anus. A perforated plate like sructure, called the Madreporite is present towards one of the interradii. A large number of calcareous spines is present on the skin (Hence the name Echinodermata for the phylum). Here and there, very small finger like processes, called the dermal branchiae, or dermal gills, project outside. These are respiratory in function. Many small pincer like calcareous structures are seen on the skin. These are called pedicellariae. These help to keep the surface of the animal clean from encrustations and algal growth. Each pedicellarium has three calcareous pieces, namely a basal piece and two valves or blades which are justapposed to each other and work like the claw of the crab.

Body-wall of the starfish has an outer cuticle and below it the epidermis. The epidermis has ciliated cells, mucous secreting cells, pigment cells, and neuro sensory cells. Beneath the epidermis is the dermis which gives rise to the dermal ossicles. These are calcareous pieces giving support to the skin and to the spines. The ossicles are named according to the positions they occupy.

Locomotion: The animal moves very slowly using its tube feet on the ventral surface. There is no definite anterior or ce-

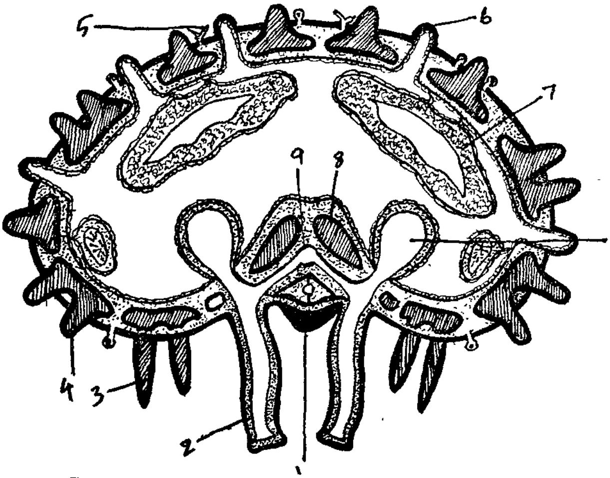

Fig. 87

T.S. Arm of Starfish 1. Radial nerve 2. Tube foot 3,4. Spines 5. Pedicellaria 6. Dermal branchiae 7 Caecae 8. Ossicles 9. Radial canal 10. Ampulla

phalic end. The tube feet end in small flat plates, which can be converted into vacuum cups or suckers by reducing pressure of liquid inside. The tube feet are attached to hard substratum and fixed to it by the vacuum method. They can be released by increasing the pressure of liquid inside. This decrease and increase in the fluid pressure inside is possible because of the water vascular system (vide infra).

Nutrition: The star fish feeds on the soft tissues of the molluscs especially bivalves. That is why star fishes are considered enemies of oysters. (oysters are commercially valuable as food and for the pearl industry) The star fish has its mouth on the ventral side, in the centre of the disc. The mouth leads into a short oesophagus which joins the stomach. The stomach has a lower big saccular structure called the cardiac stomach and a smaller part called the pyloric stomach. The cardiac stomach is eversible. The pyloric stomach has five pairs of pyloric caecae attached to it. Each pair extends dorsally into the arms

and suspended from the roof of the arm by mesenteries. These secrete digestive enzymes. The pyloric stomach leads into a short intestine. This has a few extensions or caecae before it opens dorsally at the anus.

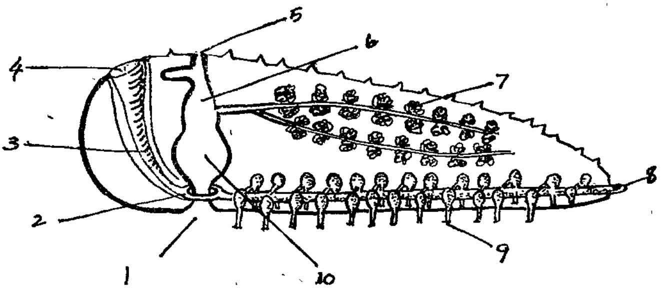

Fig. 88

Water Vascular System 1. Mouth 2. Circum oral Canal
3. Stone canal 4. Madreporite 5. Anus 6. Pyloric stomach
7. Pyloric caeca 8. Tentacle 9. Tube foot 10. Cardiac stomach

The star fish attaches its arms on the shells of the bivalve molluscs. After effecting a firm attachment, the arms are pulled apart. The force tears the adductor muscles of the bivalves and the shells are torn apart. Then the starfish everts its cardiac stomach and applies its stomach to the soft parts of the bivalves. Digestion takes place and after digestion, the cardiac stomach is withdrawn inside. This method of everting the stomach to digest the food outside is resorted to, because the opening of the mouth is very small and it cannot be dilated owing to the presence of ossicles around.

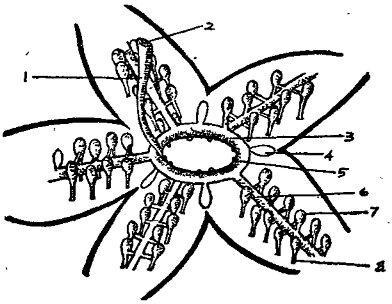

Fig. 89

Water Vascular System

1. Stone canal
2. Madreporite
3. Circum oral canal
4. Polian Vesicles
5. Tiedman's bodies
6. Radial canal
7. Ampulla 8. Tube foot

Water Vascular System: The star fishes have a peculiar circulatory system inside their body. There is a system of tubes or vessels

inside the body in which the sea water is made to circulate. This system is called the water vascular system. This is connected with the tubefeet and therefore the locomotion and feeding are also associated with this system.

The system starts from the madreporite, a perforated plate towards one interradius on the dorsal side of the disc. Sea water enters this madreporite and is taken down by a vertical stone canal. This gets the name because its wall is strengthened by calcareous deposits. This joins a circular oral ring canal surrounding the oesophagus. This ring canal gives rise to five long radial canals which proceed into the arms above the ambulacral grooves. The radial canals end at the tips of the arms as terminal hollow tenatacles. Along its entire length, the radial canals give rise to paired lateral canals. These are connected to vertical tube feet. The lower part of the tube foot is cylindrical, but dorsally it ends in a sac like ampulla. There is a valve in the lateral canal which can prevent the back ward flow of water. The entire system works like a hydraulic-pressure system.

Many amoeboid cells float in this water vascular system. In some starfishes the ring canal has 4 or 5 sac like Pollan vesicles towards the outside in the interradial position. These are helpful in regulation of pressure. Besides organs called **Tiedmann's bodies** are also seen attached to the ring canal. These produce the amoebocytes.

Respiration: This takes place by diffusion. The oxygen in the seawater diffuses in through the thin walls of the dermal-branchiae and CO_2 diffuses out.

Nervous System: There are three nerve rings namely (1) superficial (2) deep oral and (3) aboral rings. Each ring gives rise to five radial nerve cords extending into the arms.

Reproduction: The gonads are dorsally placed in the interradii of the disc. They open to the outside by genital pores. Fertilisation is external. The egg develops into a larva called Bipinnaria larva. This is bilaterally symmetrical with a C shaped

alimentary canal and two bands of cilia (hence the name Bipinnaria). It is free swimming and then metamorphoses into the radially symmetrical adult.

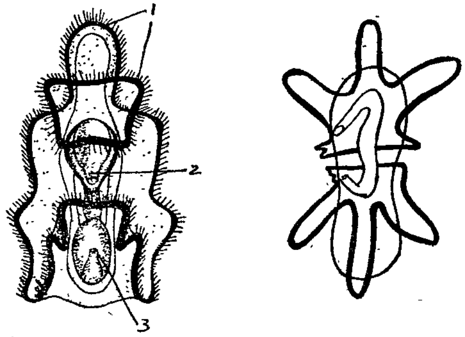

Fig. 90
Bipinnaria larva
1. Ciliary band
2. Mouth 3. Anus

GENERAL CHARACTERS OF CHORDATES

The members of the Phylum Chordata are populary known as the Chordates which have three unique characters. These are (1) the presence of a dorsal tubular nerve cord (2) the presense of a notochord and (3) the presence of gill-slits.

Nerve Cord: In the invertebrates the nerve cord is paired and ventral in position. It has a number of ganglia from which nerves are given off. In the chordates on the otherhand, there is a single unpaired dorsal tubular nerve cord, without ganglionic enlargements and extending from the anterior to the posterior end. It remains as such in the primitive chordates, but in the advanced chordates or vertebrates, it becomes specialised to form the brain and the spinal cord. The anterior part of the nerve cord develops into the brain while the posterior part becomes the spinal cord.

Notochord: This is a stiff rod like structure situated beneath the nerve cord and above the alimentary canal and extending from the anterior to the posterior end. The notochord is composed of large vacuolated cells and is covered by two sheaths of connective tissue, an inner one called the membrana elastica interna and an outer one called the membrana elastica externa. It gives rise to the vertebral column in the vertebrata. Hence it has been described as the fore runner of the back bone. The notochord forms a stiff axis for the soft bodied prochordates while in the vertebrates it also acts as a fulcrum for the attachment of muscles which are helpful in locomotion.

Gill Slits: The gill slits are apertures found on the lateral wall of the pharynx. In the primitive chordates their number is very large. While in the higher vertebrates it is fewer in number and rarely exceeds more than Seven pairs. The gill slits serve primitively for the passage of water from the pharynx to the outside. The current of water is both nutritive and respiratory in function. In fishes associated with the gill slits, the gills

develop and these are richly supplied with blood vessels. Exchange of gases takes place between the blood supplied to the gills and the water passing through the gill slits. In fishes, the gill slits with the gills form the respiratory organs throughout life. In the terrestrial forms such as lizards, birds and mammals on the otherhand, the gill slits are present only in the embryo and they are nonfunctional. In the amphibians such as frogs, the gill slits are functional only in the larval stages, but disappear in the adult, their function being taken up by the lungs.

4. The epidermis in the Chordates consists of several layers of cells. In the nonchordates the epidermis is composed of a single layer of cells.

5. The epidermal specializations such as scales, feathers, hair are common in the chordates. While in the non-chordates the epidermis secretes the shell and the cuticle.

6. The body can be divided into a head trunk and the tail. The head and the trunk are connected by a neck.

7. The presence of a complex head formed by the fusion of the anterior segments termed as cephalization is a characteristic feature of chordates. It has a full complement of sense organs such as the eyes, ear, nose and the taste buds (buccal cavity).

8. The presence of a post anal tail. In all the nonchordate the anus is terminal in position.

9. The trunk is charactefised by the presence of two pairs of appendages. The appendages are in the form of fins in the fishes and limbs in the other vertebrates.

The limbs are suitably modified to fit into the modes of life of the vertebrates.

They are constructed on a common basic plan. They are of the pentadactyl type [(penta-five) (dactyl-digit).]

10. Chordates are characterised by a definite endoskeleton. It is mostly bony in character in the adults with the exception of the elasmobranchs which have a cartilagenous endoskeleton throughout.

11. The heart is ventral to the alimentary canal. It is a highly muscular, chambered structure and it is formed of only cardiac muscle fibres.

12. Chordates are characterised by the presence of two portal systems namely (1) hepatic portal system in connection with the alimentary canal and the liver and (2) renal portal system in connection with the kidneys.

13. The red blood corpuscles are nucleated and they contain the respiratory pigments namely haemoglobin and haemocyanin.

14. Excretion is performed by definite excretory organs termed the kidneys. Three different types of excretory organs namely pronephros, pmesonephros and metanephros make their appearence in the chordates. Kidneys are composed of basic excretory units termed as the nephrons. These are comparable to the nephridia of the non chordates.

15. The circulatory system is of the closed type throughout.

16. Respiration is effected by either the skin, gills or the lungs.

17. Gonads are limited to only one pair. Distinct gonoducts meant for carrying the generative cells are present.

18. A distinct endocrine system composed of endocrine glands is characteristic of vertebrates. These secrete the organic compounds called the hormones which control growth, development of skeleton, metamorphosis and secondary sexual characters.

19. Hermaphroditism is rare or absent in the majority of vertebrates.

20. The other characters of the chordates include (a) Bilateral symmetry, (b) the presence of three germ layers namely ectoderm, endoderm and mesoderm, (c) the presence of different organ systems, (d) presence of a coelom.

Classification of Chordata

The Phylum Chordata is subdivided into four subphyla namely Subphylum Hemichordata, Subphylum Urochordata, Subphylum Cephalochordata and Subphylum Vertebrata. The first three subphyla are collectively known as the Prochordates.

Subphylum Vertebrata: The vertebrates are characterised by the presence of a stiff bony vertebral column or back bone. The nerve cord, notochord and gill slits occur only during the embryonic stages. The nerve cord gives rise to the brain and spinal cord, the notochord develops into the vertebral cloumn and gill slits disappear early during the development except in the case of the fishes where they are functional throughout life. With the exception of the fishes, in all the vertebrates respiration is effected by means of the lungs in the adults.

The subphylum vertebrata is divided into five classes namely (i) Pisces (Fishes); (ii) Amphibia (frogs and toads); (iii) Reptilia (lizards, crocodiles, snakes, turtles, tortoises); (iv) Aves (birds); and (v) Mammalia (rabbit, whale, horse, man, pig, monkey).

Class (1) Pisces: The fishes are aquatic cold blooded or Poikilothermic vertebrates. Typically the body of a fish is streamlined or boat shaped facilitating easy progression in water. The entire body is covered over by backwardly directed scales. They are all dermal in origin (derived from the dermis of the skin) and are arranged overlaping each other just like the tiles on a roof.

The body of the fish is divisible into the head, the trunk and the tail. The head bears the mouth, eyes and nostrils. The eyes are supported by three eyelids, an upper eyelid, a lower eyelid and a transparent third eyelid or the nictitating membrane. The nostrils are olfactory in function. The trunk bears the fins which help in locomotion and the tail bears the caudal fin. Locomotion is effected by the flexions of the body aided by the fins. Fins are of two types namely the paired and unpaired fins. Paired fins are of two kinds, the pectoral and pelvic fins. Pectoral fins are comparable to the forelimbs of other vertebrates while the pelvic fins can be compared to the hind limbs. The pectoral fins are generally situated on the lateral sides, just behind the head. The pelvic fins are placed at different levels, but they are generally abdominal in position. The unpaired fins include the dorsal, the anal and the caudal fins. The dorsal fins may be one or two in number and are present along the mid-dorsal line. Anal fins or ventral fins as the name indicates are found near the anal apperture while the caudal fin is found fringing the tail. Pectoral and pelvic fins help in propelling the fish forwards while the dorsal fin prevents the fish

from rolling over to the sides. The caudal fin helps in changing the direction of swimming. Respiration is performed with the help of the gills. Normally five pairs of gills are seen. The heart is made up of two chambers, namely an auricle and a ventricle. Sexes are separate. Majority of them are oviparous. However a few such as the shark are viviparous.

There are two categories of fishes namely the cartilagenous fishes and the bony fishes. Sharks and rays are cartilagenous fishes because the internal skeleton is composed of cartilage while Mugeil, Salmon, Macrones are bony fishes since the internal skeleton consists of bones.

Class (2) Amphibia: The class includes the frogs, toads caecilians and salamanders. The amphibians are capable of leading a double mode of life (i.e.) they can live in water as well as on land. They are cold blooded or poikilothermic vertebrates. The true aquatic amphibians resort to gill respiration while the others breath with the aid of the lungs and the skin. The body which is compact and rigid is covered by the skin which is smooth and slimy devoid of scales. It is divisible into. three regions namely, the head, the trunk and the tail. The tail however may or may not be present. A distinct neck is absent. The head bears the mouth, a pair of well developed eyes and tympanum. The eyes are provided with eyelids and a transparent nictitating membrane as in fishes. The trunk bears the fore and hind limbs. The limbs are of the pentadactyl type and are concerned with locomotion. In some cases the limbs are reduced. The heart is made up of three chambers namely two auricles and a ventricle. A distinct cloaca is present. Sexes are separate. In the life history of the frog there is a fish like larval stage called the tadpole. Examples: Frog, Toad, Salamanders, Newts, Caecilians etc.

Class (3) Reptilia: The reptiles are true terrestrial vertebrates while some of them such as the turtles, crocodiles, sea snake etc., have become secondarily aquatic. They are cold blooded vertebrates in which the body is covered over by a dry scaly skin. The scales are epidermal in origin. The body can be divided into three regions namely the head, the trunk and the tail. The head is connected with the trunk by a movable neck.

The head bears at the tip, a pair of pin hole like apertures called the external nostrils and at the sides a pair of well developed eyes which are protected by three eyelids an upper eyelid, a lower eyelid and a thin transparent nictitating membrane. The trunk bears the fore and hind limbs. The fore limb can be divided into four regions namely the upper arm, the fore arm, the wrist and the hand. The hind limb likewise can be divided into four regions the thigh, the shank, the ankle and the foot. The limbs are of pentadactyl type. The fingers and toes terminate in claws. Respiration is effected with the pair of lungs. The heart is incompletely four chambered consisting of two distinct auricles and an incompletely divided ventricle. A distinct cloaca is present through which the undigested food materials, the genital products and the nitrogenous waste products are sent out. Sexes are separate. Majority of the reptiles are oviparous while a few such as the sea snakes are viviparous, giving birth to the young ones. There is no larval stage in development, the young ones resembling the adult except in their size. (e.g.) Calotes (garden lizard), Gecko (house lizard), Naja naja (cobra) Varanus (monitor lizard), Crocodiles, Turtles and Tortoises.

Class (4) Aves: The birds are adapted for an aerial mode of life. They are warm blooded or homoiothermic vertebrates unlike the fishes, amphibians and reptiles. They are popularly referred to as the "feathered tribe of the animal kingdom." The body of the bird is covered by a feathery coat. The feathers are epidermal in origin. There are three types of feathers namely (1) quill feathers (2) contour feathers and (3) filoplumes. The filoplumes occur in between the contour feathers. The quill feathers are present on the wings and plumes. The contour feathers are found covering the general body surface. The wing feathers are known as the remiges and the tail feathers as the rectrices. The feathers are arranged along definite tracts called pterylae in between which there are featherless tracts known as the apteria.

The body of the bird can be divided into three distinct regions namely a head, trunk and the tail. The head bears the beak, the nostrils and a pair of well developed eyes. There is a neck connecting the head and the trunk. The trunk bears the fore and the hind limbs. The fore limbs are modified to form he wings. By flapping the wings the birds are able to soar up

and sustain themselves in the air. The hind limbs are attached far up in the trunk and this enables the bird to bear the weight of the body when it is at rest. The legs are covered with scales. The beak is modified according to the mode of feeding. Teeth are completely absent in the modern birds but were present in the ancient fossil birds. The body temperature is very high ranging upto 40° C.

Respiration is effected with the aid of the lungs. Associated with the lungs there are air sacs, the presence of which is a characterestic feature of the birds. The heart is four chambered consisting of two auricles and two ventricles. Birds are strictly oviparous. Certain birds such as the ostriches, the cassowaries, the kiwis etc., are flightless while the great majority such as the crows, sparrows, pigeons, vultures etc., are endowed with the power of flight.

Class (5) Mammalia: The mammals are the most highly specialised of the vertebrates. These are mostly terrestrial, but a few forms like whales, seals, walruses etc. have become secondarily aquatic. Like the birds, the mammals are warm blooded animals maintaining a constant body temperature irrespective of the surrounding temperature. The body is covered with hair and hence the mammals are referred to as the 'hairy tribe of the animal kingdom'. The body of a mammal can be divided into three regions namely the head, the trunk and the tail. However a tail may or may not be present. The head bears a pair of eyes, external nostrils and ear lobes or pinnae. The presence of ear lobes or pinnae is a characterestic feature of the mammals and those are meant for receiving the sound waves produced in the terrestrial environment. The trunk is divisible into an anterior bony thorax and a posterior abdomen. The thorax contains the lungs and the heart. The thorax and abdominal cavities are separated by a muscular partition called the diaphragm. The heart is completely divided into four chambers. The brain is highly developed, the cerebral surface showing a number of convolutions. A band of nervous tissue called the corpus callosum connects the two halves of the cerebrum. The red blood corpuscles are non nucleated. The skin contains sweat glands and the sebaceous glands. With the exception of certain very primitive mammals, the others are all viviparous. A pair of scrotal sacs are present in the males.

CHAPTER XI

External Morphology

Mugeil : Mugeil is popularly known as Mullet. It is a common edible fish found in the seas, estuaries, and brackish waters of India. There are several species of mullets. The more common ones are Mugeil cephalus, Mugeil parsia, Mugeil oeur etc., They are herbivorous forms. Some of them feed on the mud present at the bottom. They develop to a length of six to twelve inches.

The body is typically fish-like-streamlined. This is meant for breaking through the column of water. The body can be divided into three regions, namely, the head, trunk and the tail, The head is slightly depressed. The entire body is covered by overlapping scales resembling the arrangment of the tiles on a roof. The scales are developed from the dermal region of the skin. The scales are of the Ctenoid type. The scales are characterized by concentric lines and these are bisected by radiating ridges. The free end of the scale it produced into spines. The presence of spines is a characteristic feature of Ctenoid scale.

The head has a terminal mouth, a pair of nostrils and a pair of eyes on the sides. The eyes are without the eyelids. The mouth is bounded by upper and lower jaws. The jaws are devoid of teeth. Mouth leads into the buccal cavity. The posterior end of the head has a pair of semicircular flap, gill cover or opercula. These cover the delicate gills and thus afford protection to them.

The trunk is laterally compressed and it supports paired and unpaired fins. Fins are characteristic of fishes and are the organs concerned with locomotion. The fins are of two types. The paired fins and the unpaired fins. Both types of fins are membrane-like structures supported internally by bony elements

termed as fin rays. The paired fins include the pectorals and the pelvics. The pectoral fins are present behind the opercula one on either side. The pelvic fins are ventral in position close

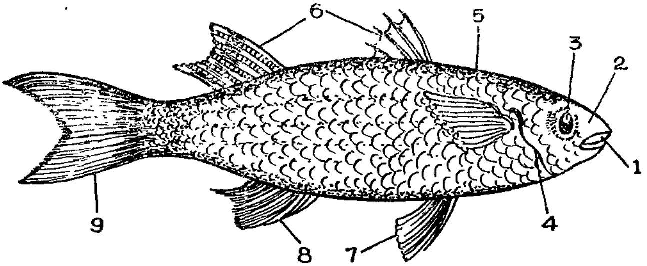

Fig. 91
Mugeil-External Features
1. Mouth 2. External nostrils 3. Eye 4. Operculum
5. Pectoral fin 6. Dorsal fin 7. Pelvic fin 8. Anal fin
9. Caudal fin.

to the pectoral fins. The unpaired fins include the two dorsal fins, the anal or the ventral fin and the caudal fin. The two dorsal fins are found on the mid-dorsal line of the trunk. The first dorsal fin is supported by 4 to 5 bony fin rays. The tip of the bony fin rays are spiny. The second dorsal fin is close to the caudal fin. It is supported by soft fin rays. The anal fin or ventral fin, as the name indicates is present close to the

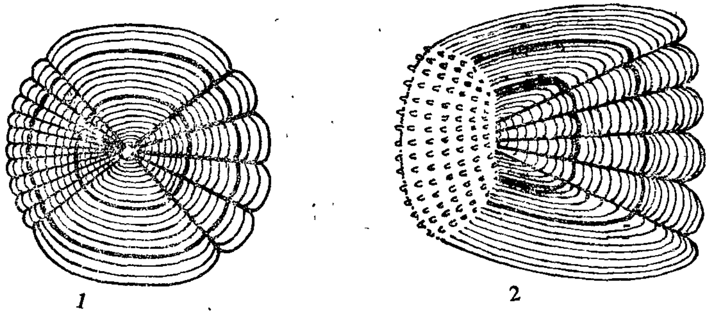

Fig. 92 Mugeil-Scales
1. Cycloid scale 2. Ctenoid Scale

anus. It is also supported by soft fin rays. The caudal fin supports the tail. It is of the homocercal type. It is formed of a dorsal and ventral lobe equal in size. Internally the finrays are more

well developed on the ventral side. The dorsal and ventral fins by their oscillating movements serve to balance the body and prevent the fish from rolling on its sides. The caudal fin by its lashing movements serves to change the direction of swimming. The pectoral and the pelvic fins by their movements serve to steer the fish forwards. Anus is situated about two thirds from the anterior end. The urino genital apertures are present behind the anus.

FROG (Rana hexadactyla) : The common frog is very often found living in or near water. It belongs to the class Amphibia, a group which attempted to colonise the land thus representing the pioneers among the terrestrial vertebrates and naturally it shows adaptations for life both on land and in water. The amphibia occupy an intermediate position between the fish like ancestors and are themselves ancestral to reptiles.

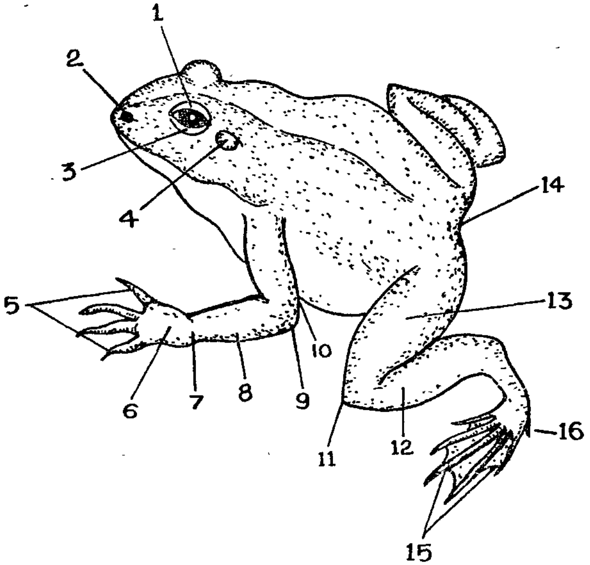

Fig. 93 Rana hexadactyla: External Features.

1. Upper eyelid 2. External nostril 3. Lower eyelid 4. Tympanum 5. Fingers 6. Palm 7. Wrist 8. Fore arm 9. Elbow 10. Upper arm 11. Knee 12. Shank 13. Thigh 14. Cloaca 15. Web. 16. Calcar

There are several species of frogs, the common ones of which are Rana hexadactyla characterised by six toes in the hind-limbs

(hexa-six; dactyl-digit) the sixth toe being invisible as it is concealed beneath the skin, Rana cyanophlictis and Rana tigrina characterised by stripes on the skin.

The body of the frog is short and oblong and is divided into two parts namely the head and the trunk. A distinct neck is absent. A tail also is absent in the adults. The body is covered over by a loosely attached smooth moist skin. It is slimy to touch and is totally devoid of any skeletal structures. The head is triangular in shape with a wide mouth in front and it merges invisibly with the trunk. The mouth is bounded by upper and lower jaws. On the dorsal side of the head close to the tip of the snout is a pair of external nostrils or the external nares, which can be closed or opened by thin flap like extensions of the skin. Behind the nostrils, two prominent eyes are present one on each side of the head. Each eye is protected by upper and lower eyelids. The upper eyelid is thick, fleshy and immovable and has the same colour as the surrounding skin. The lower eyelid gives rise to a thin transparent nictitating membrane, which functions as a protective structure. It can be drawn over the eyes and it keeps the eyes moist and clean when the animal is on land and protect them when it is in water. Behind each eye, there is a dark circular patch of stretched skin known as the tympanic membrane or the ear drum.

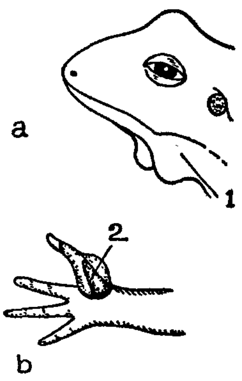

Fig. 94
Rana hexadactyla : Sexual dimorphism
a. Head
b. Hand of a male frog
1. Vocal sac
2. Nuptial pad

The trunk is broad and some what flattened and bears two pairs of limbs on the sides. The fore-limbs are short and are situated anteriorly while the hind-limbs are longer, admirably adapted for jumping and swimming. Each fore-limb consists of an upper arm or brachium, the fore-arm or antebrachium and a hand or manus. The hand is made up of the wrist or carpus, the palm or metacarpus, and the fingers or digits. There are only four fingers in each fore-limb, the finger corresponding to our thumb or pollex being absent. Each

hind-limb consists of a thigh or femur, shank or crus and foot or pes. The foot is made up of the ankle or tarsus, the instep or metatarsus and the toes or digits. There are five webbed toes in each hind-limb, which aid in swimming. The fourth toe is the longest, the third and fifth toes are equal in size, the second is shorter than the fifth and the first or inner most toe is the shortest of all. At the posterior end of the trunk and situated dorsally between the base of the hind-limbs, is a small aperture called the cloacal aperture. The frog is said to be a tetrapod since it has two pairs of limbs and the limbs are described as penta-dactyl since they bear five digits each.

The frog exhibits sexual dimorphism. The male can be distinguished from the female during the breeding season by the presence of a pair of vocal sacs near the angles of the jaws and by the presence of a thick pad of tissue on the index finger called the nuptial pad. The latter helps the male to grasp the female during copulation.

GARDEN LIZARD (Calotes Versicolor): It is a common lizard found in gardens and hence the popular name gardenlizard. It is a diurnal form. It feeds on insects. It is a quadripedal form. It develops to a length of about 10 to 12 inches or more including tail.

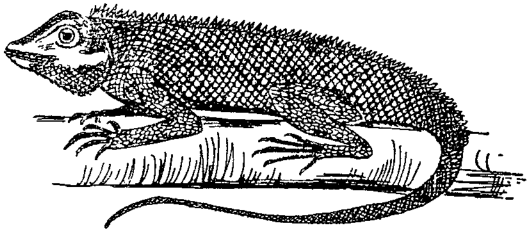

Fig. 95

Calotes versicolor (garden lizard)

The body is divisible into three regions namely the head, the trunk and a long tail. The head is connected to the trunk by a distinct neck. The body is covered by horny scales which develop from the epidermis of the skin. It is different from the scales of the fish which are dermal in origin. The scales present in the mid dorsal line of the head and trunk are modified to form spine like structures termed as dorsal crest.

The head has a pair of external nostrils at its tip. The nostrils are a pair of pin-hole like apertures. The front portion of the head is termed as the snout. A pair of prominent eyes are present one on either side of the head. Each eye is supported by a thick upper eyelid and a thin lower eyelid which can be drawn over the eye like a shutter termed as *nictitating membrane*. A pair of auditory openings covered by the tympanic membranes are present behind the eyes. These are slightly below the surface of the head. The mouth is wide and it is bounded by upper and lower jaws provided with teeth.

The trunk is laterally compressed and it bears a pair of fore-limbs and a pair of hind-limbs. These are helpful in the crawling type of locomotion and as well serve to bear the weight of the body. The fore and the hind-limbs bear five fingers and five toes respectively. These are provided with powerful claws which are helpful in digging or burrowing. The parts of the fore-limb and the hind-limb are similar to those of frog. Cloacal aperture is a transverse slit present at the base of the tail. The tail is long and whip like.

PIGEON (**Columba Livia**) : It is a common South Indian bird. It is popularly known as the Pigeon. It is a gramnivorous foim. It is a typical flying form.

The body is divisible into a rounded head, a flexible neck, a short stout trunk and a stumpy tail. The body is covered by feathers. The feathers are characteristic of birds.

The head is drawn out in the front into a beak. It has the mouth. The presence of a beak is a characteristic feature of the birds. With the help of the beak they pick up the insects or the grain or pinch off parts of the plant. The base of the beak has a pair of pinhole-like apertures. These are the external nostrils. On the lateral sides of the head are present the eyes. Each eye is supported by an upper eyelid, a lower eyelid and a nictitating membrane. Behind the eyes are a pair of ears. These lead into a tube which has at its base a tympanic membrane.

The trunk supports the fore and the hind-limbs. The fore-limbs are modified to form a pair of wings which are the organs

of flight. The wings are supported by wing feathers which are epidermal in origin. The wing feathers are arranged in a row along the wings. These are also termed as the quill feathers or the remiges. The fore-limbs show three divisions namely the

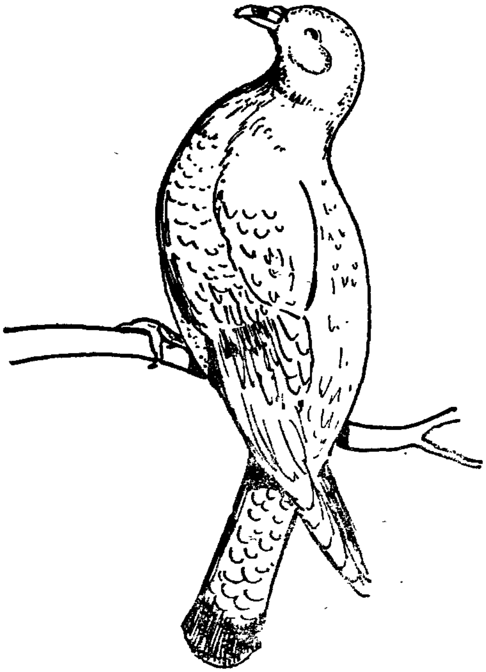

Fig. 96 Columba livia: External features

upper arm, fore-arm and the hand which bears the three fingers. The wings can be kept folded when the bird is at rest and it is extended laterally during flight. The hind-limbs are attached higher up on the trunk and they serve to bear the weight of the body. The terminal part of the leg is not covered by the feathers but by scales. The hind-limbs preserve the same parts as found in the frog.

The tail is small and stumpy and it bears the tail feathers or rectrices. These are helpful in changing the direction during flight. The cloaca is situated at the hind end of the trunk.

Feathers: Feathers are exoskeletal structures. Feathers are arranged in definite tracts called the pterylae. In between, the

featherless tracts are termed as apteria. The feathers are lodged in definite pits on the skin termed as the feather follicles. There are three types of feathers namely (1) Quill feathers (2) Contour or down feathers and (3) Filoplumes.

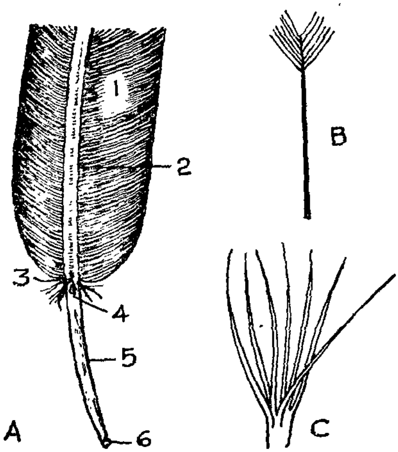

Fig. 97 Pigeon-Feather
A. Quill feather B. Contour feather
C. Filoplume

1. Vane 2. Rachis 3. Aftershaft
4. Superior umbilicus 5. Quill
6. Inferior umbilicus

Quill feather: These are found in the wings and the tail. Each quill feather has two portions i.e. a hollow tubular or cylindrical basal portion termed as quill or calamus and an upper broad smooth flat portion termed as the vane. The quill has two openings namely, the inferior umbilicus at the base and a superior umbilicus at its apex. At the junction between the quill and the vane a few hair-like structures are present termed as

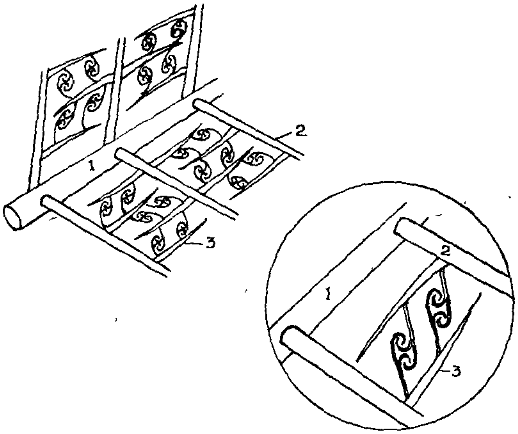

Fig. 98 Bird—Feather Structure
1. Rachis 2. Barb 3. Barbule

the aftershaft. The vane has a central stiff rachis. The rachis supports closely arranged hair-like structures termed the barbs.

The barbs inturn give rise to laterally placed hair-like barbules. The free end of the barbules are provided with hook-like structures, termed, the barbicels. The barbicel of one barbule is interlocked with the barbicel of the adjacent barbule. This interlocking system gives the smoth flat surface to the vane.

Down feathers or Contour feathers: These are found all over the surface of the trunk and the hind legs (except for the terminal portion of the hind legs). Each contour feather is formed of a short stem which has free barbs. Barbules and barbicels are absent. They give a definite shape to the body.

Filoplumes: These are slender hair-like structures with a coat of hairs at the apex. They are found beneath the contour feathers.

RAT (Rattus rattus) : It is a common household mammal. The related form namely the field rat (Gerbillus indicus) is found in the paddy fields. The house rat has a naked scaly tail while the field rat has a hairy and bushy tail.

The body is divisible into a head, trunk and a tail. The head and trunk are connected by a short neck. The body is covered by hairs which are epidermal in origin. The presence of hair is a characteristic feature of the mammals.

The head is conical in shape and front part is distinguished as snout. The tip of the snout has a pair of external nostrils and a few hair-like structures termed, the vibrissae. These are sensory in function. The mouth present at the tip of the snout is bounded by fleshy upper and lower lips. This is a characteristic feature of mammals. A pair of well developed eyes are present on the lateral sides of the head. Each

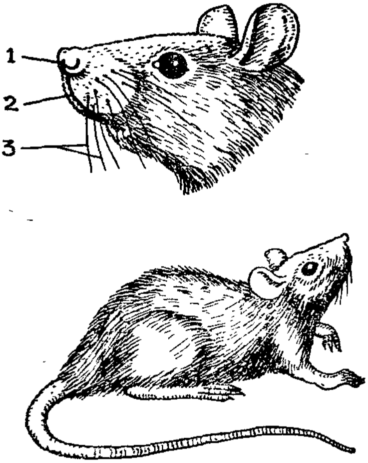

Fig. 99
Rattus rattus–External features
1. External nostril
2. Cleft upper lip
3. Whiskers

eye is supported by an upper and a lower eyelid and a nictitating membrane. The eyelids are supported by eyelashes. The presence of eyelashes is characteristic of mammals. A pair of funnel shaped cartilagenous pinnae are present meant for receiving the sound waves. The pinnae lead into a tube called the external auditory meatus at the base of which is the tympanum. The presence of pinnae is a characteristic feature of mammals.

The trunk is divisible into an anterior bony thorax bounded by sternum and the ribs and a posterior soft walled abdomen. Trunk on the ventral side in the female has small prominences termed as teats. These are characteristic of mammals. The teats are small and undeveloped in the males. In the males a pair of scrotal sacs and a muscular penis are present at the posterior end of the trunk. The scrotal sacs enclose the testes. This is a characteristic feature of mammals. Anus is situated at the base of the tail. The urinogenital aperture is found on the ventral side in front of the anus. The space between the anus and the urinogenital aperture is the perineum. A pair of perineal pouches are present one on either side of the anus. The trunk supports a pair of fore-limbs and a pair of hind-limbs. The divisions of fore-limbs and hind-limbs are similar to that of the frog. The fore and the hind-limbs are provided with five fingers and five toes respectively. Tail is elongated and ringed. Rat is a viviparous form giving birth to young ones.

CHAPTER XII

Digestive System

MUGEIL: It includes the alimentary canal and the digestive glands. The alimentary canal is a long highly coiled, tubular, muscular structure. It consists of mouth, buccal cavity, pharynx, oesophagus, stomach, duodenum, ileum, rectum and opens to the outside as the anus. Anus is situated in the ventral side of the trunk close to the anal fin. Mouth is terminal in position. It leads into the buccal cavity. It is bounded by upper and lower jaws. Teeth are absent in the mullet. The buccal cavity leads into pharynx. The lateral walls of the pharynx are perforated by 4 pairs of gill slits. The posterior wall of the pharynx has a number of pharyngeal teeth. These serve as strainer or as a filtering apparatus. It serves to strain the mud from the food materials present in it. Pharynx leads into stomach. Stomach consists of two parts namely an anterior cardiac stomach and a posterior thick muscular globular pyloric stomach. The cardiac stomach gives rise to small blind finger-shaped caecum. Pyloric stomach gives rise to five finger-shaped glandular structures termed as the pyloric caecae. The presence of pyloric caecae

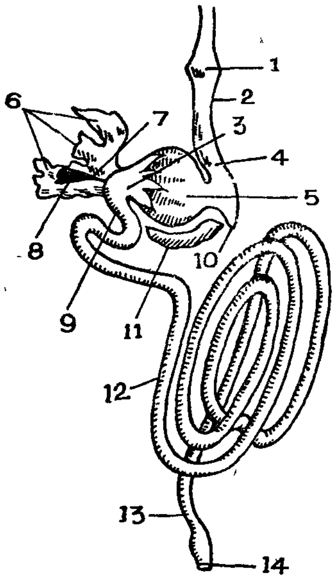

Fig. 100

Mugeil–Digestive System

1. Pharynx 2. Oesophagus
3. Pyloric caecae 4. Cardiac stomach
5. Pyloric stomach 6. Liver
7. Bile duct 8. Gall bladder
9. Duodenum 10. Caecum 11. Spleen
12. Ileum 13. Rectum 14. Anus

is a characteristic feature of bony fishes. The stomach is followed by the duodenum which leads into highly coiled ileum or intestine. The presence of such a highly coiled intestine is a characteristic feature of herbivorous fishes. Ileum is followed by a short rectum which opens to the outside through anus.

The digestive glands include the liver and the pancreas. Liver is the largest digestive gland dark red in colour and is incompletely divided into three lobes. It secretes the bile juice which is stored in a small sac-like structure called gall bladder. It is embedded on the lower margin of the right lobe. A distinct duct termed the bile duct leads from the gall bladder into the duodenum.

The Pancreas: The Pancreas is an elongated cream coloured gland lying in the loop between the stomach and the duodenum. It is made up of a number of lobes in which pancreatic juice is secreted. The pancreatic juice is conveyed into the common bile duct by a main pancreatic and several smaller ducts.

The spleen is a small dark rounded structure attached to the mesentery between the ileum and the rectum. It is found in close association with the alimentary canal but has no digestive function. It is a well developed lymphoid structure manufacturing new red blood corpuscles and at the same time disposing off the old ones.

FROG: The digestive system is concerned with the chemical break down of complex food materials into simple assimilable substances. The digestive system consists of the alimentary canal and its associated glands.

Alimentary Canal: The alimentary canal is essentially a muscular tube consisting of the mouth, buccal cavity, the pharynx, the oesophagus, the stomach, the duodenum, the ileum and the rectum which opens out by the cloaca. The mouth leads into a wide buccal cavity, bounded by upper and lower jaws. The upper jaw bears a row of fine conical maxillary teeth along its margin. The lower jaw is devoid of teeth. On the roof of the buccal cavity, a little behind the anterior end, is a pair of vomerine teeth. The teeth prevent the prey from escaping and are not meant for mastication. At the anterior end of the roof of

the buccal cavity are two internal nostrils or nares which communicate to the exterior through the external nostrils. On the floor of the buccal cavity lies a sticky protrusible muscular tongue bifid at its tip. The tongue is folded backwards when not in use but can be suddenly flicked out when capturing the prey. The pharynx is imperfectly delimited from the buccal cavity. Opening into it are two wide laterally placed apertures called eustachian openings which lead into the tympanic cavity of the middle ear. At the posterior region of the floor of the buccal cavity is a small median longitudinal slit called the glottis which opens into the laryngotracheal chamber. The pharynx leads into a very short muscular oesophagus. The inner lining of the oesophagus is folded longitudinally to allow for expansion during the passage of food. The oesophagus leads gradually into the muscular stomach. The stomach is more or less elongated. The anterior part of the stomach is larger and wider and is distinguished as the cardiac stomach while the posterior part which is slightly narrow is distinguished as the pylorus, respresenting the reduced pyloric stomach. The pyloric stomach leads into the small instestine called the duodenum although it is not clearly demarcated from the rest. At the junction of the pyloric stomach and duodenum is a slight constriction called the pylorus which contains in its wall a sphincter composed of circular muscle fibres called the pyloric sphincter. The common hepato-pancreatic duct opens into the duodenum. The duodenum leads into the next region of the small intestine, the ileum which is the longest part of the alimentary canal and is thrown into

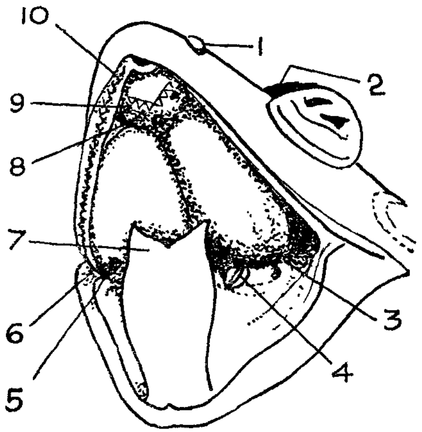

Fig. 101

Frog: Buccal Cavity

1. Nostrils 2. Eye 3. Pharynx
4. Glottis 5. Eustachian recess. 6. Upper Jaw 7. Tongue 8.*Interal nostrils
9. Vomerine teeth 10. Maxillary teeth.

several coils. This increase in length provides a large absorptive surface which is further enhanced by the folding of its lining membrane. The ileum opens into the rectum. The rectum in turn opens into the cloaca.

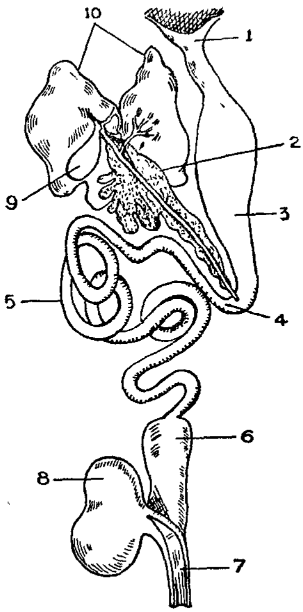

Fig. 102

Frog : Digestive System

1. Oesophagus 2. Pancreas
3. Stomach 4. Duodenum
5. Ileum 6. Rectum
7. Cloaca 8. Urinary bladder
9. Gallbladder 10. Liver

Associated Glands: Two important glands are associated with the digestive system and these are the liver and the pancreas. **The liver:** The liver is a large reddish-brown gland situated in the anterior part of the body cavity. It is made up of two lobes namely a large right lobe and a slightly smaller left lobe, divided into two lobes. Each lobe is in turn made up of lobules, in which the bile is secreted and it is carried by the bile capillaries which unite to form a single bile duct which traverses the pancreas and opens into the duodenum. The bile is temporarily stored in a small rounded sac of greenish colour called the gall-bladder, which lies between the right and left lobes of the liver.

CALOTES: It includes the alimentary canal and its associated digestive glands. It consists of mouth, buccal cavity, pharynx, oesophagus, stomach, duodenum, ileum, caecum and rectum which opens into the cloacal chamber. The cloacal chamber opens to the outside as the cloacal aperture. It is present at the base of the tail as a transverse slit. Mouth is a wide opening bounded by bony jaws. Jaws contain teeth. The teeth are fused to the innerside of the jaw bones. This kind of teeth is termed as pleurodont type. The buccal cavity at its posterior end has a pair of eustachian recesses. The floor of the buccal cavity has a muscular tongue. A small slit like aperture at the posterior end of the tongue termed glottis is present. It leads into the

larynx. The buccal cavity leads into a thin walled pharynx which in turn gives rise to a short thick muscular tubular

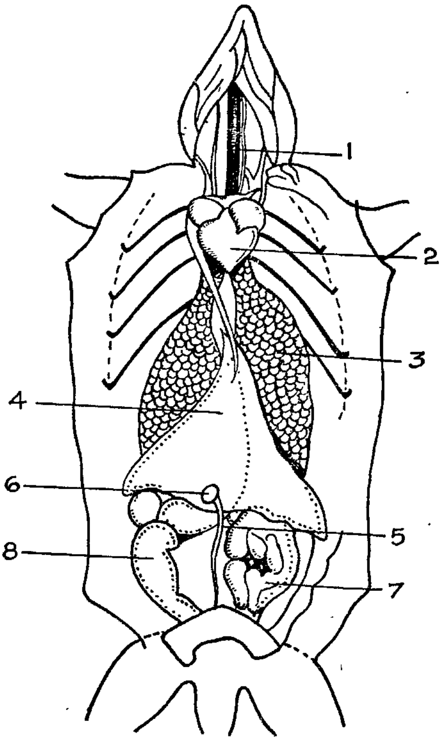

Fig. 103 Calotes: Viscera
1. Trachea 2. Heart 3. Lungs
4. Liver 5. Abdominal vein 6. Gall bladder 7. Ileum 8. Rectum.

oesophagus. The oesophagus leads into the stomach where the food is stored and partially digested. The posterior end of the stomach leads into a tubular duodenum. The stomach and the duodenum form a distinct U shaped curvature. Duodenum leads into slightly coiled ileum which leads into the rectum. At the junction between the ileum and the rectum is a small blind caecum. The rectum opens into the cloacal chamber. The cloaca is divided into three compartments namely an anterior coprodaeum receiving the rectum, a middle uro-

daeum into which open the urinogenital ducts and a posterior proctodaeum which opens to the outisde as the cloacal aperture

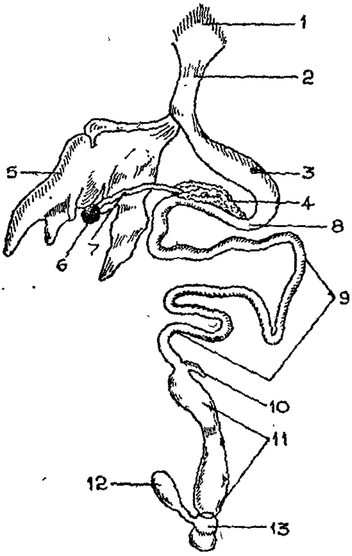

Fig. 104

Calotes : Digestive System

1. Pharynx 2. Oesophagus
3. Stomach 4. Pancreas 5. Liver
6. Gall bladder 7. Bile duct
8. Duodenum 9. Ileum 10. Caecum
11. Rectum 12. Urinary bladder
13. Cloaca

The digestive glands include the liver and the pancreas. Salivary glands are absent. The liver is made up of two lobes a right and the left. It secretes the bile juice which is stored in the sac-like gall bladder. It is embedded in the right lobe of the liver. Bile duct leads from the gall bladder into the duodenum. It serves to conduct bile juice from the gall bladder into the duodenum. Pancreas is a diffused structure attached to the inner end of the duodenum. It gives rise to the pancreatic duct which opens into the duodenum along with the bile duct. Calotes is a carnivorous form and feeds on insects which it captures with the help of the jaws and the tongue.

COLUMBA LIVIA: It consists of the alimentary canal and the digestive glands. The alimentary canal includes the mouth, buccal cavity, pharynx, oesophagus, stomach, duodenum, ileum, and rectum which opens ino the cloaca. The mouth is bounded by the upper and lower jaws which have become modified to form the beaks. Teeth are absent. Mouth leads into the buccal cavity. The floor of the buccal cavity has a muscular immovable tongue. A single eustachian aperture is present behind the tongue. The buccal cavity leads posteriorly into the pharynx. Pharynx leads into the oesophagus which is enlarged to form a thin walled crop. The crop serves to store the food. Oesophagus leads

into the stomach which is divided into two portions namely an anterior tubular proventriculus and a posterior thick walled gizzard. The proventriculus has gastric glands. The gizzard helps in grinding the food into a pulpy mass. This is followed by a distinctive hairpin like U shaped duodenum followed by a highly coiled ileum which leads into the rectum. A pair of rectal caecae is found at the junction of the ileum and the rectum. As in the lizard the cloacal aperture is divisible into three regions namely an interior coprodaeum, a middle urodaeum and a posterior proctodaeum. A small sac termed bursa fabricii opens into the proctodaeum.

The digestive glands include the buccal glands, gastric glands the liver and the pancreas. Three pairs of buccal glands open into the mouth. Based upon their position they are termed the parotid, maxillary and the sublingual glands. The liver consists of two unequal lobes, a larger right lobe and a smaller left lobe. Each lobe gives rise to a bile duct. One of them opens into the duodenum close to the gizzard while the other opens into the portion of the duodenum close to the ileum. The pancreas is a diffuse structure attached to the inner end of the duodenum close to the gizzard. It has three pancreatic ducts and they all open into the terminal part of the duodenum. The gall bladder is absent. Pigeon is a gramnivorous form.

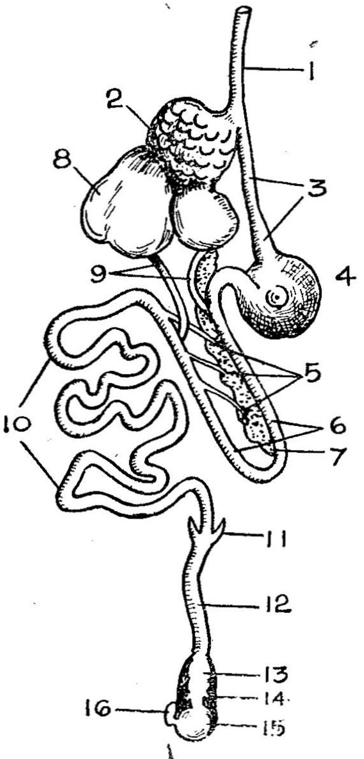

Fig. 105
Columba Livia–Digestive System
1. Oesophagus 2. Crop
3. Proventriculus 4. Gizzard
5. Pancreatic ducts 6. Duodenum 7. Pancreas 8. Liver
9. Bile ducts 10. Ileum
11. Rectal caecum 12. Rectum
13. Coprodaeum 14. Urodaeum
15. Proctodaeum 16. Bursa fabricii.

RATTUS RATTUS : It consists of the alimentary canal and the digestive glands. The alimentary canal consists of the mouth, buccal cavity, pharynx, oesophagus, stomach, duodenum, ileum, caecum, colon and rectum which opens to the outside as the anus situated at the posterior end of the trunk. The mouth is bounded by fleshy lips and it leads into the buccal cavity. It is bounded by upper and lower jaws. The jaws contain the teeth. The arrangement of the teeth in the jaw bones is termed as dentition. The teeth are different from the other vertebrates. They are embedded in definite sockets or alveoli present in the jaw bones. This kind of dentition is termed as thecodont type. The teeth are of different sizes and shapes. They are: 1. Incisors 2. Canines 3. Pre-Molars and 4. Molars. This type of dentition is termed as the heterodont type. The arrangement of the teeth can be expressed in the form of a dental formula as follows:

$$\frac{I}{I} :: \frac{C}{C} : \frac{PM}{PM} : \frac{M}{M}$$

In the rat canines and the pre-molars are absent. It has a limited number of teeth namely sixteen, eight in the upper jaw and eight in the lower jaw. The dental formula for rat is

$$I : \frac{1}{1} : C \frac{O}{O} : PM \frac{O}{O} \; M \frac{3}{3}$$

The floor of the buccal cavity has a muscular tongue. The buccal cavity leads into a tubular oesophagus which passes through the middle of the neck and the thorax and enlarges into a sac-like stomach on the leftside of the abdomen. It pierces through a dome shaped diaphragm. The wall of the stomach contains the gastric glands. It is followed by a U shaped duodenum and a highly coiled ileum. There is a slightly enlarged caecum at the junction between the ileum and the colon. The colon

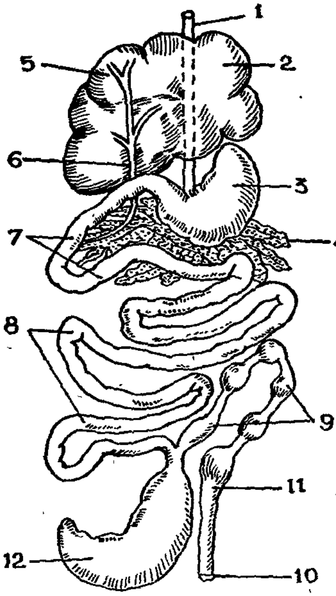

Fig. 102

Rattus—Digestive System
1. Oesophagus 2 and 5. Liver 3. Stomach 4. Pancreas 6. Bile duct 7. Duodenum 8 Ileum 9. Large intestine 10. Anus 11. Rectum 12. Caecum

leads into the rectum which opens to the outside through anus.

The digestive glands include the salivary glands, the gastric glands, the liver, the pancreas and the intestinal glands. The salivary glands include the submaxillary, sublingual the parotid and infraorbital glands. The salivary juice secreted by these glands is conducted into the buccal cavity by means of tubular ducts. The gastric glands are found embedded in the wall of the stomach. They secrete the gastric juice. The intestinal glands are present embedded in the wall of the intestine. They secrete the intestinal juice. The liver is dark red in colour and it is made up of five distinct lobes. These are present beneath the diaphragm. Gall bladder is absent. Single bile duct opens in to the duodenum. Pancreas is a diffuse leaf shaped structure present beneath the stomach. It secretes the pancreatic juice which is conducted into the duodenum by means of pancreatic duct. Rat is an omnivorous form.

CHAPTER XIII

Blood vascular system

The blood vascular system is a closed system consisting of delicate branched tubes connected with each other known as the blood vessels. The circulating medium namely the blood travels inside these tubes. The blood vascular system is composed of the heart, the arteries, the veins and the capillaries. The heart is a conical muscular organ responsible for maintaining the circulation of blood in the blood vessels. These are two types of blood vascular systems in animals viz. the open type and the closed type. The open type of circulatory system is met with in leeches, molluscs and arthropods. In this case the blood vessels are very much reduced or absent and the blood stream is represented in the form of thin-walled spaces or sinuses filled with blood. A heart is invariably present and a few vessels are found in connection with it which are responsible for the circulation of blood into these sinuses. The closed type is met with in most annelids, cephalopods and vertebrates. It is composed of the heart and blood vessels. The circulating medium is contained in a system of tubes called blood vessels which are of four types namely arteries, arterioles, capillaries and veins. From the capillaries food materials diffuse into the tissue through the tissue fluids. In a similar way waste products of tissues are conveyed back to the blood. The volume of blood unlike in the open system is limited and is circulated quickly and hence the pressure of blood is very high. In the closed type, circulation of blood is kept up, by the alternate contraction and relaxation of the heart.

General Plan of the Circulatory System

In higher animals the circulatory system consists of a pumping centre called heart and a complicated set of tubes called blood vessels. The existence of heart, arteries and veins in the

bodies of higher animals has been known for thousands of years though the significance of their presence was not understood for a very long time. The circulation of blood was discovered by William Harvey and this paved the way for the better understanding of the process of nutrition, respiration, secretion and excretion.

Blood Vessels: There are four main types of blood vessels (1) the arteries (2) the arterioles (3) the capillaries and (4) the veins.

Arteries: The arteries are mainly concerned with carrying pure blood from the heart to the capillary system. There is an exception to this generalization viz. the pulmonary artery of vertebrates which instead of carrying pure blood, carries impure blood from the heart to the lungs for purification. The wall of an artery is composed of three distinct layers or coats or tunics—an inner, middle and outer. The inner coat is known as the tunica interna. It is composed of single layer of endothelial cells. The middle coat is the tunica media which is composed of smooth muscles and elastic connective tissue fibres. It is many layered in thickness. The outer coat is the tunica adventitia and is composed of connective tissue mixed up with elastic fibres which form a network. The elasticity of the arteries is mainly due to the presence of elastic fibres in its wall.

Arterioles: This is the name given to the smallest tubes of the arterial system. Their walls are mainly composed of smooth muscles arranged circularly around the vessels.

Capillaries: These vessels are very thin walled. Their walls are made up of a single layer of endothelial cells. They are supplied with fine nerve endings. These smaller tubes anastomose and form a very fine network of minute tubes. The capillaries are found as a result of the branching of arterioles. The capillaries reunite to form a vein.

Veins: The veins collect the blood from the capillaries in the tissue and empty into the heart. Veins like arteries are composed of three coats. The tunica media is poorly developed and hence the veins are thin-walled. Many of the larger veins

have valves which aid the flow of blood towards the heart The veins usually carry impure blood to the heart from the capillary system. There is an exception to this rule, viz. the pulmonary veins of vertebrates carry pure blood instead of impure blood from the lungs to the heart.

Heart: The heart of vertebrates exhibits a gradually increasing complexity of structure in relation to the evolutionary progress of the different groups.

Heart in Mugeil: The heart in the Mugeil is formed of two chambers namely the auricle or atrium and the ventricle. The heart is present behind the gills. The sinus venosus is a thin-walled structure at the base of the heart receiving blood from the different parts of the body. Mainly it functions as a reservoir from which the blood flows into next chamber, the atrium. The atrium is a large thin-walled muscular chamber situated dorsal to the ventricle and anterior to the sinus venosus. From the atrium the blood enters the ventricle through an opening, the atrio-ventricular opening, guarded by valves. The ventricle has very thick muscular walls and its anterior end is enlarged to form the bulbus arteriosus. It has a single row of pocket like valves. It is continued as the ventral aorta. In the fish only the impure blood passes through the heart and hence it is termed as the branchial heart.

FROG : Circulatory System: The vascular system consists of a pumping organ called the heart and a complicated network of tubes called blood vessels. The blood which forms the circulating medium is present in these blood vessels, and it is kept in circulation through the different parts of the body by the pumping action of the heart. Since the vascular system is a closed one the blood eventually returns to the heart. The blood vessels leaving the heart are the arteries. When these vessels reach the tissues they divide into thin-walled capillaries. The blood vessels coming back to the heart are the veins. The arteries and veins are connected by capillaries. So the blood flows from the heart through the arteries into capillaries and from these through the veins back to the heart.

Heart in Frog: The heart of frog is a muscular dark red conical organ lying in the anterior part of the body cavity on the

ventral side and at the level of the forelimbs. The heart is enclosed in a double walled thin bag called the pericardium. The two layers of the pericar dium are continuous at the base of

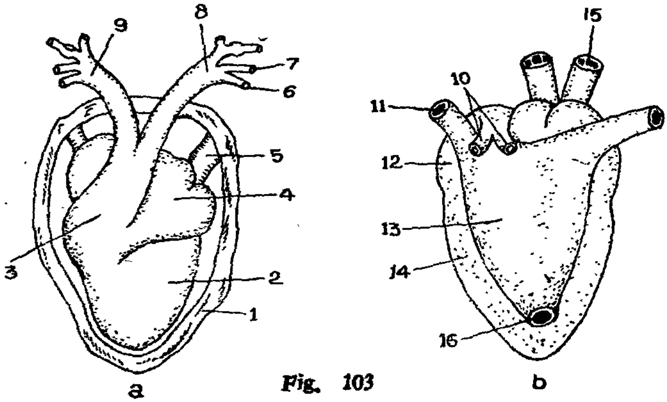

Fig. 103

Frog — Heart

a. Dorsal view b. Ventral view

1. Pericardium 2. Ventricle 3. Truncus arteriosus 4. Right auricle 5. Precaval vein 6. Pulmocutaneous arch 7. Systemic arch 8. Carotid arch 9. Right truncus arteriosus 10. Pulmonary vein 11. Precaval vein 12. Left auricle 13. Sinus venosus 14. Ventricle 15. Left truncus arteriosus 16. Post caval vein

the heart. In between these layers is a cavity which is filled with the pericardial fluid. The fluid protects the heart from shocks and injuries due to friction. On removing the pericardium, the heart can be seen to consist of a single conical thick-walled ventricle with its apex pointing posteriorly and two anterior thin-walled auricles. On the dorsal side of the heart there is a triangular chamber called sinus venosus. Opening into the sinus venosus at its three corners are three large venous trunks namely a pair of antero lateral precaval veins which bring venous blood from the head, shoulder and the forelimbs and a single posteriorly situated post caval vein which brings venous blood from the posterior parts of the body. The sinus venosus opens into the right auricle by the sinu auricular aperture. On the ventral side of the heart is present a cylindrical vessel the truncus arteriosus or conus arteriosus which arises from the base of the ventricle and runs obliquely forwards.

Internal structure of the heart: The internal structure of the heart is rather complicated. The upper two auricles are separated from one another by a longitudinal septum called the inter auricular septum. The sinus venous opens into the right auricle by the sinu auricular aperture through which the venous blood is emptied into the right auricle. The edges of the sinu auricular aperture are produced into a pair of lip like structures which by apposition prevent the backward flow of blood. The pulmonary veins bringing arterial blood from the lungs unite and the common vein opens into the left auricle by a small opening in its dorsal wall. This opening is not guarded by any valve. Since it is obliquely placed the pressure caused by the contraction of the auricles serves to close the opening. The right and left auricles together open into the single ventricle by a common auriculo ventricular aperture. This opening is guarded by four valves, the auriculo ventricular valves, which hang down into the cavity of the ventricle. These valves prevent the backward flow of blood from the ventricle into the auricles when the ventricle contracts. Projecting into the ventricular cavity from the muscular wall are a number of papillary muscles which make the ventricle spongy. Connecting the free ends of the auriculo ventricular valves with the free ends of the muscles are fibrous strands called chordae tendinae. The chordae tendinae prevent the valves from being pushed back into the auricles when

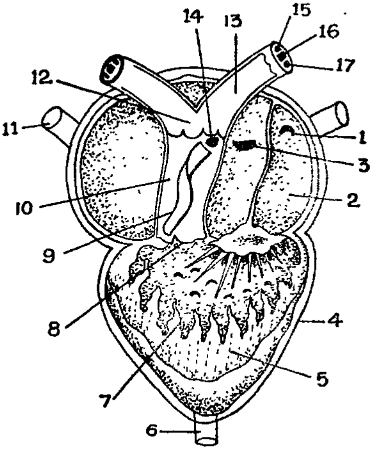

Fig. 104
Frog—Heart

1. Opening of the pulmonary vein 2. Left auricle 3. Sinu auricular opening 4. Parietal layer of the pericardium 5. Visceral layer of the pericardium 6. Post caval vein 7. Ventricle 8. Semilunar valves 9. Spiral valve 10. Truncus arteriosus 11. Prevacal vein 12. Carotid artery 13. Origin of the systemic arch 14. Origin of the pulmonary artery 15. Carotid arch 16. Systemic Arch 17. Pulmocutaneous arch.

the ventricle contracts. From the right side of the base of the ventricle arises the truncus arteriosus and it is guarded by 2 to 4 semilunar valves. There are cuplike or pocket like valves the closed ends of which face the ventricle while their open ends are directed forward into the truncus arteriosus. Because of this arrangement the semilunar valves allow the flow of blood into truncus arteriosus from the ventricle but not in the reverse direction. There is a spiral valve in the truncus arteriosus.

Working of the heart: The circulation of blood is maintained by rhythmic contractions of the heart. The contraction phase (systole) and relaxation phase (diastole) takes place in a regular sequence. The sinus venosus contracts first followed by auricles, the ventricle and finally the conus arteriosus. When the sinus venosus contracts, the venous blood which it has received from the body is forced into the right auricle through the sinu-auricular aperture. At the same time the left auricle receives arterial blood brought by the common pulmonary vein. Now the two auricles contract simultaneously. As a result the blood is forced into the ventricle through auriculo-ventricular aperture, the backward flow of the blood into the sinus venosus being prevented by the sinu auricular valves.

The right side of the ventricle receives venous blood from the right auricle while the left side of the ventricle receives arterial blood from the left auricle. The mixing up of the blood in the ventricle is minimised due to its spongy nature and immediate contraction after receiving the blood. As a result the blood enters the truncus arteriosus flowing between the semilunar valves. The mixed blood flows uniformly into the three arterial arches at the same time. This is the modern working hypothesis of the working of the heart of frog, put forth by Vandervael and Foxon (1948 : 1951). Vendervael injected Indian ink into the pulmonary veins of pithed frogs and showed by illuminating the heart and blood vessels from below and observing through suitable binocular microscope from above that blood entered simultaneously in all the three trunks. Foxon has confirmed this observation (by injecting radium opaque material thorostrat in the veins of frog) that there is no selective supply of blood to the head. From this we can conclude that the spiral valve does not play a part in the direction of blood flow.

It only acts as a mechanical support to the truncus arteriosus. On the basis of more recent researches it is established that the carotid gland acts more as a sensory organ in detecting pressure changes as in higher vertebrates than in regulating the flow of arterial blood to the head. Further it appears that pulmonary respiration helps only to a little extent in frog and that the major part of respiration is achieved by the skin and the buccal cavity.

Heart of a Lizard: In the lizard the heart is incompletly four chambered being a pair of disctinct auricles and a ventricle partially divided by a septum. The right auricle receives venous blood from the various parts of the body through the two precavals and a single post caval. The left auricle receives oxygenated blood from the lungs through pulmonary veins. The right systemic springs from the left side of the ventricle, while the left systemic springs from the right side of the ventricle. The heart is enclosed in a thin walled pericardium.

Heart of a Bird: The avian heart is comparatively larger in size and is made up of four distinct chambers namely a pair of auricles above and a pair of ventricles below. It has the same structure as that of a mammal except for the following differences: (i) Of the two systemic arches only the right one is present, the left having disappeared. It arises from the left ventricle of the heart then curves around the heart and passes behind it as aorta. (ii) The opening of the right auricle into the right ventricle or right auriculo-ventricular opening is guarded by a single flap representing the right auriculo-ventricular valve.

Heart of Rat: The heart of the rat lies in the mediastinal space in the thorax between the two lungs. It is somewhat conical in shape with its broad base directed forwards and the blunt apex pointing downwards and slightly to the left.

A longitudinal section of the heart reveals that it is made up of four chambers namely two thin walled auricles above and two thick walled *muscular* ventricles below. The auricles and ventricles are separated by an auriculo—ventricular septum. The two auricles are separated from each other by an inter auricular septum, and the two ventricles by an inter ventricular septum. As a result of this there is a complete separation of the aerated

and non-aerated blood in the heart. The sinus venosus and the conus arteriosus found in frog are absent in the rat, the former being absorbed into the right auricle and the latter divided into the pulmonary artery and the aorta. Consequently the three main veins, the two precaval veins and the single post caval vein, open directly into the right auricle. The pulmonary artery arises from the right ventricle while the aorta from the left ventricle. Into the left auricle open the two pulmonary veins. The right auricle communicates with the right ventricle by a wide opening the right auriculo-ventricular aperture. This opening is guarded by a valve, the tricuspid valve composed of three membranous lobes or cusps. The left auricle communicates with the left ventricle by the left auriculo-ventricular aperture. This aperture is guarded by a valve, the bicuspid valve or mitral valve composed of two flaps. These valves prevent the regurgitation of blood from the ventricles into auricles. These flap like valves hang down into the ventricular cavity and their free edges are attached to muscular processes of the walls of the ventricle called papillary muscles by means of tendenous threads, the chordae tendinae. The chordae tendinae prevent the valves from being pushed into the auricles by the pressure of the blood during ventricular contraction. From the right ventricle arises the pulmonary artery which divides into two branches one entering each lung. From the left ventricle arises the aorta which curves to the left side and passes backwards supplying blood to the various parts of the body. At the commencement of the pulmonary artery and the aorta, there are 3 pocket like semilunar valves which prevent the backward flow of blood into the respective ventricles.

Arterial System of Mugeil: It includes the heart and arteries.

The heart is present just behind the gills in the body cavity. It is made up of two chambers namely an auricle and a ventricle. The ventricle receives the sinus venosus. The auricle gives rise to a small bulbus arteriosus. It has a simple row of pocket like valves. The bulbus arteriosus is continued as the ventral aorta, which passes in between the gills. It gives rise to four pairs of afferent branchial vessels. They break off into capillaries in the wall of the gills. The ventral aorta carries impure blood to the gills. The capillaries unite to form the efferent branchial vessels. These are four pairs of efferent bran-

chial vessels. These open into a ring like blood vessel termed as the circulus cephalicus. Anteriorly it carries blood to the head through the carotid arteries. Posteriorly the circulus cepha-

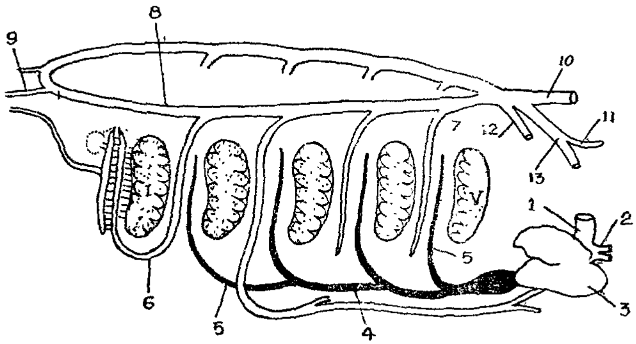

Fig. 105

Mugeil—Arterial System

1. Cavuerian duct 2. Liver 3. Heart 4. Ventral aorta 5. Afferent branchial artery 6. Efferent branchial artery 7. Epibranchial artery 8. Circulus cephalicus 9. Carotid artery 10. Dorsal aorta 11. Artery to the air bladder 12. Coeliac artery 13. Mesenteric artery

licus unite to form the dorsal aorta. The dorsal aorta gives rise to the coeliac artery to the stomach, mesenteric to the intestine and the renal arteries to the kidneys. Posteriorly it is continued as the caudal artery into the tail.

Arterial system of Frog: The arterial system begins with the truncus arteriosus arising from the base of the ventricle on the right side. It divides into a right and left branch. Each branch divides into three aortic trunks namely an anterior carotid supplying blood to the head, a middle systemic supplying blood to the rest of the body and a posterior pulmocutaneous supplying venous blood to the lungs and skin for oxygenation.

The carotid trunk divides into two branches namely a lingual artery and a carotid artery. The lingual artery supplies blood to the thyroid muscles of the hyoid and the tongue. The carotid artery is large and at its base there i s a carotid gland. This gland is a spongy structure which is believed to be a sensory structure and regulates the flow of blood into the carotid. The carotid artery runs forwards and gives rise to an interna

carotid, that supplies blood to the brain, and a palatine artery which supplies blood to the roof of the mouth and the orbit.

The two systemic trunks pass dorsally around the oesophagus run backwards and unite to form the dorsal aorta which runs towards the posterior part of the body along the mid dorsal line. Each systemic trunk gives off a laryngeal to the throat

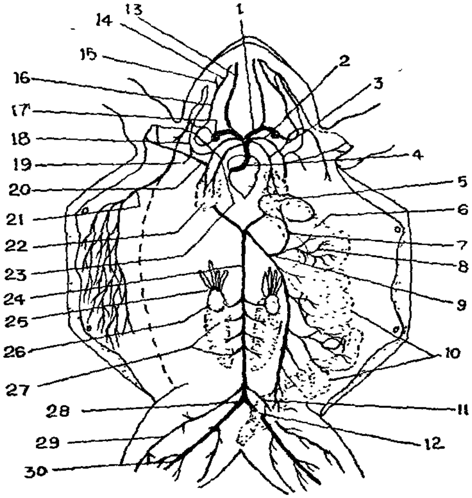

Fig. 106 Frog—Arterial System

1. Carotid artery 2. Systemic artery 3. Pulmo utaneous artery 4. Truncus arteriosus 5. Liver 6. Stomach 7. Hepalic artery 8. Coeliac artery 9. Coeliaco mesenteric artery 10. Ileum 11. Posterior mesenteric artery 12. Rectum 13. Lingual artery 14. Palatine artery 15. Internal carotid artery 16. Carotid artery 17. Carotid labyrinth 18. Occipital artery 19. Vertebral artery 20. Subclavian artery 21. Cutaneous artery 22. Lungs 23. Pulmonary artery 24. Dorsal aorta 25. Fat body 26. Testis 27. Pulmonary artery 28. Common iliac artery 29. Femoral artery 30. Sciatic artery

region, an occipito vertebral artery which divides into an occipital supplying the skull and a vertebral supplying the vertebral column and a subclavian artery which after giving of branches to the shoulder and the body wall is continued into the arm as the brachial artery.

The dorsal aorta runs beneath the vertebral column and gives off an unpaired coeliaco mesenteric which divides forming the coeliac supplying the stomach and liver and the anterior mesenteric supplying the small intestine, spleen. The doral aorta then runs backwards between the kidneys and gives off four pairs of renal arteries to the kidneys. From the renal artery of each side a gonadial artery arises supplying the gonad and the fat body. The dorsal aorta also gives off one to four lumbar arteries running to the dorsal body wall. Near the posterior end of the dorsal aorta a small posterior mesenteric artery arises to the rectum. At the posterior end, the dorsal aorta bifurcates into two arteries, the common iliacs. Each common iliac gives rise to (i) the vesiculo epigastric artery supplying the urinary bladder and the ventral body wall (ii) the femoral artery supplying the outer part of the thigh (iii) the sciatic artery supplying the rest of the hindlimb. Each pulmocutaneous trunk divides into two branches namely the pulmonary artery which breaks up into capillaries in the lungs and the cutaneous artery which gives off a number of branches distributed all over the skin.

Circulatory system of Lizard (Calotes) : The circulatory system is composed of the heart, arterial system and venous system.

Heart: In the lizard the heart is incompletely four chambered, consisting of two distinct auricles and an incompletely divided ventricle. This is due to the incomplete nature of the inter ventricular septum. The heart is covered by a pericardium. The right auricle receives venous blood from the various parts of the body through the two precavals and a single post caval. The left auricle receives oxygenated blood from the lungs through the pulmonary vein. The right systemic springs from the left side of the ventricle while the left systemic springs from the right side of the ventricle.

Arterial system in Lizard: The truncus arteriosus takes its origin from the right side of the ventricle on the ventral side of the heart. Unlike the condition in the frog, in the lizard the truncus arteriosus is divided into three arches right from the base namely the carotid, the systemic and the pulmonary arches which are connected together by connective tissue. The carotid arch is the anterior-most of the three arches. It divides into an external carotid and an internal carotid. These arteries supply blood to the dorsal and ventral region of the head.

The two systemic arches curve around the heart and unite posterior to it to form the median dorsal aorta. The right systemic arch arises from the left side of the ventricle while the left systemic arises from the right side. These two trunks cross near the base. The systemic arch and the carotid arch on each side are connected by a small lateral blood vessel termed the ductus caroticus, a characteristic feature with the circulatory system of the garden lizard. The right systemic arch gives rise to the left as well as the right subclavian arteries. This is another peculiar feature found in the garden lizard. The dorsal aorta gives rise to the following arteries (i) paired intercostal arteries supplying the muscles of the ribs (ii) an unpaired anterior mesenteric supplying the anterior part of the intestine and the duodenum (iii) an unpaired coeliac artery supplying the sto mach, the spleen, the pancreas and the liver (iv) an unpaired posterior mesenteric artery to the rectum (v) paired gonadial arteries supplying the gonads (testes or ovaries) (vi) three pairs of renal arteries in the region of kidneys (vii) paired iliac arteries to the hindlimbs (viii) the dorsal aorta is continued as the caudal artery to the tail. The pulmonary trunk conveys venous blood into the lungs for aeration.

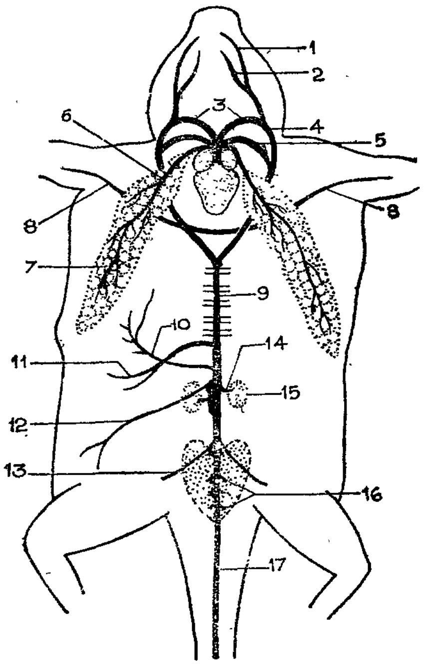

Fig. 107

Lizard—Arterial system

1. Internal carotid 2. External carotid 3. Carotid 4. Ductus caroticus 5. Systemic 6. Pulmonary 7. Lungs 8. Sub clavian 9. Dorsal aorta 10. Anterior mesenteric 11. Coeliac 12. Posterior mesenteric 13. Iliac 14. Gonadial 15. Gonad 16. Renal 17. Caudal

Arterial system in Bird: In the birds the heart is completely four chambered. A distinct conus is absent and only the rgiht

systemic arch and the pulmonary trunk are present. The right systemic arch arises from the left ventricle.

It curves around the heart and gives off the right and left innominate arteries. Each innominate artery divides into a carotid artery and a subclavian artery. The carotid artery supplies blood to the head. The subclavian divides into a brachial artery supplying blood to the arm and a pectoral artery to the muscles of the wings. The right systemic arch curves around the heart and is continued as the dorsal aorta. From the dorsal aorta arises the following vessels. (i) an unpaired coeliac artery supplying blood to the stomach, intestine and liver (ii) the unpaired anterior mesenteric artery supplying the major part of the intestine (iii) paired anterior renal arteries to the anterior lobes of the kidneys (iv) paired femorals to the anterior portions of the thigh (v) paired sciatics to thepo-sterior regions of the thigh and legs. From the sciatics arise the middle and the posterior renal arteries supplying the middle and the posterior renal lobes (vi) an unpaired posterior mesenteric to the rectum

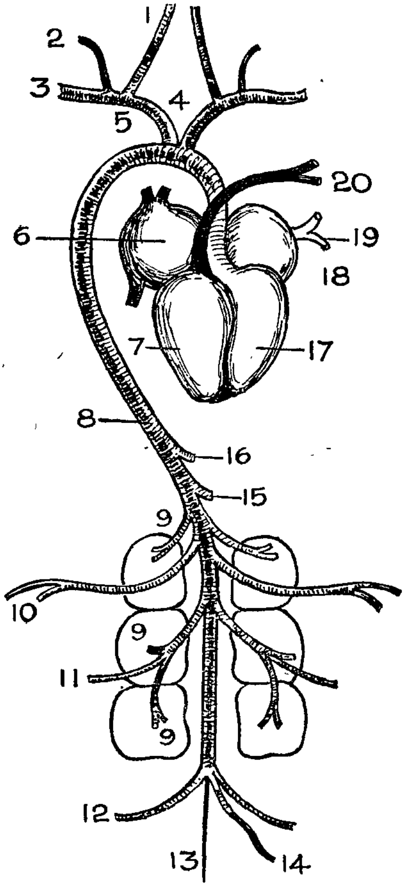

Fig. 108 Bird—Arterial System

1. Common carotid 2. Brachial 3. Pectoral 4. Innominate 5. Subclavian 6. Right auricle 7. Right Ventricle 8. Dorsal aorta 9. Renal arteries 10. Femoral 11. Sciatic 12. Iliac 13. Caudal 14. Posterior mesenteric 15. Arterior mensenteric 16. Coeliac 17. Left ventricle 18. Left auricle 19. Pulmonary vein 20. Pulmonary trunk.

and cloaca (vii) paired internal iliacs to the pelvis and (viii) the caudal artery which is a continuation of the aorta into the tail.

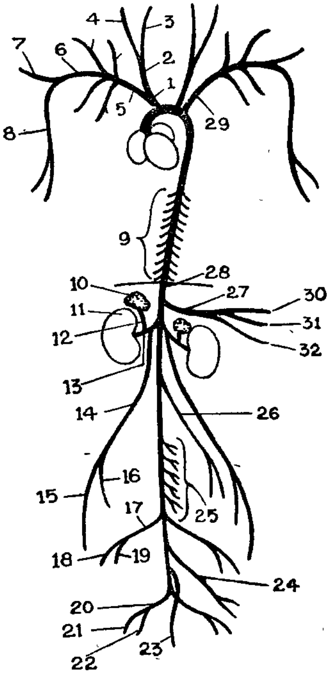

Fig. 109

Rat—Arterial System

1. Innominate 2. Common right carotid 3. Internal carotid 4. External carotid 5. Subclavian 6. Axillary 7. Sub scapular 8. Brachial 9. Inter costal 10. Supra renal 11. Kidney 12. Supra renal artery 13. Renal artery 14. Gonadial 15. Testicular 16. Epididymal 17. Ilio lumbar 18. Iliac 19. Lumbar 20. Common iliac 21. External iliac 22. Internal iliac 23. Caudal 24. Inferior mesenteric 25. Lumbar 26. Superior mesenteric 27. Coeliac 28. Diaphragm 29. Subclavian 30. Splenic 31. Gastric 32. Hepatic

Arterial system of Rat: The heart is completely four chambered and there is a complete separation of pure and impure blood in the heart of rat. The right ventricle gives rise to the pulmonary trunk which after emerging from the heart divides into right and left pulmonary arteries carrying the impure blood to the lungs for purification. The left ventricle gives rise to the left systemic arch. It carries the pure blood to the different parts of the body. In the mammal the right systemic arch is absent. The presence of a single (left) systemic arch is characteristic of mammals. This condition is opposite to that of the condition prevalent in the birds where only the right systemic arch is present.

The left systemic arch curves around the heart and it is continued as the dorsal aorta posteriorly. On the anterior side the left systemic arch gives rise to, on the right side, an innominate artery. It divides into a common carotid artery and a subclavian artery. The common carotid divides into an internal carotid and an external carotid artery. The external carotid artery supplies blood to the muscles of the neck, the pharynx, the ton-

gue, the jaws while the internal carotid supplies blood to the brain. The subclavian artery gives off a number of arteries namely the (i) the vertebral artery to the cranial cavity (ii) thyro-cervical artery to the muscles of the neck (iii) brachial artery to the forelimbs which divides into a radial and ulnar artery (iv) the internal mammary artery to the muscles of the chest and (v) costocervical artery to the lateral muscles of the thorax.

On the left side the common carotid and the subclavian arise independently from the left systemic arch and hence an innominate artery is absent. They give rise to the same branches as that of the right side.

The dorsal aorta gives rise to the following branches :

(i) paired intercostal arteries to the intercostal muscles,

(ii) an unpaired coeliac artery dividing into branches supplying the spleen, stomach and the liver,

(iii) paired renal arteries to the kidneys,

(iv) each renal artery gives rise to an adrenal artery to the adrenals,

(v) a pair of spermatic arteries if it is a male also arises from the renal artery. It supplies blood to the testis, epididymis, scrotal sacs, etc.

If it is a female paired ovarian arteries arise from the renals and they supply the ovaries, fallopian tubes and uterus.

(vi) an unpaired superior mesenteric artery supplying the small intestine, pancreas and colon,

(vii) unpaired lumbar arteries supplying blood to the muscles of the lumbar region,

(viii) paired iliolumbar dividing into iliac and lumbar supplying their respective regions,

(ix) an unpaired inferior mesenteric artery supplying the colon and rectum.

The dorsal aorta splits into two common iliac arteries each entering its respective hindlimb. Each common iliac divides into an external iliac which is continued as the femoral supplying blood to the thigh and the internal iliac supplying muscles of

the thigh and muscles of the pelvis. A caudal artery arises from the dorsal aorta just above the junction where the dorsal aorta splits into common iliac arteries.

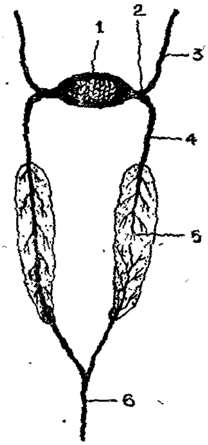

Fig. 110
Mugeil—Venous System
1. Sinus vensous
2. Cuvierian duct
3. *Anterior Cardinal* sinus 4. *Posterior car*dinal sinus 5. Kidney
6. Caudal.

Venous System of Mugeil: The impure blood is collected by the anterior cardinal veins, the posterior cardinal veins, renal portal vein and the caudal vein. The anterior cardinal veins collect impure blood from the anterior side of the body. *The posterior cardinal veins collect blood from the kidneys.* These two open into cuvierian ducts right and left. The cuvierian ducts open into the sinus venosus. The caudal vein collects blood from the tail and as it enters into the trunk it divides into two veins namely the right and the left *posterior cardinal sinuses. The right passes through the* kidney and is continued as the posterior cardinal vein where as the left breaks off into capillaries. Hence it is termed as renal portal vein. The blood from the pelvic fins is collected by iliac veins and poured *into the posterior cardinal sinuses.*

Venous System of Frog: *The venous system comprises the veins which carry* blood from various parts of the body *to* the heart. The arterial blood from the lungs is returned by the right and left pulmonary veins which unite before opening into the left auricle. The venous blood from the various parts of the body is returned to the sinus venosus by three large veins namely *the right* and left precaval veins and a post-caval vein.

Each precaval vein is formed by the union of three veins *namely the external jugular, the innominate* and the subclavian veins. The external *jugular is in turn formed by the union of* a lingual vein from the tongue and a mandibular vein from the lower jaw. The innominate is formed by the union of the internal jugular vein, from the brain, eye and other parts of the head and the subscapular vein from the shoulder and back of th

arm. The subclavian is formed by the union of the brachial vein from the forelimb and the musculo-cutaneous from the muscles of the trunk and the skin.

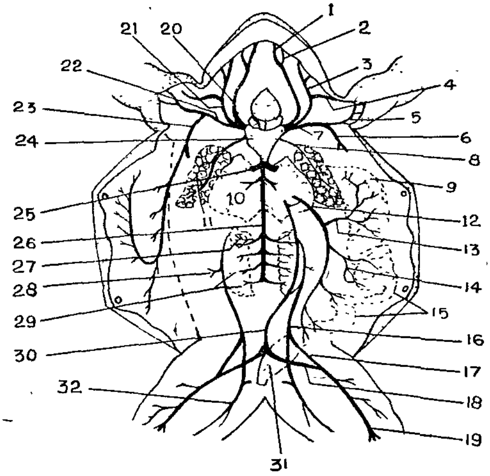

Fig. 111 Rana hexadactyla—Venous System

1. Lingual 2. Mandibular 3. Internal jugular 4. Subscapular 5. Brachial 6, 23. Musculo cutaneous 7. Precaval 8. Pulmonary 9. Stomach 10. Liver 11. Lung 12. Hepatic portal 13. Gastric 14. Duodenal 15. Ileum 16. Renal portal 17. Femoro renal 18. Pelvic 19. Femoral 20. External jugular 21. Innominate 22. Subclavian 24. Sinus venosus 25. Hepatic 26. Post caval 27. Kidney 28. Dorsolumbar 29. Renal vein 30. Anterior abdominal 31. Rectum 32. Sciatic.

The post–caval vein is situated ventral to the dorsal aorta and is formed posteriorly by the union of four pairs of renal veins emerging from the kidneys and the gonadial veins from the gonads.

Anteriorly the post-caval vein passes through the liver and in its course receives two hepatic veins from the liver and then opens into the posterior end of the sinus venosus.

The blood from each hindlimb is drained by two veins namely an outer femoral and an inner sciatic. Each femoral vein as

soon as it reaches the trunk bifurcates into two branches namely the femoro renal vein lying dorsally and the pelvic vein lying ventrally. The femoro renal vein passes forward, unites with the sciatic vein and forms the renal portal vein. The renal portal vein enters the kidney at is outer border. Just before entering the kidney it receives the dorso lumbar veins from the muscles of the back. Inside the kidney the renal portal vein breaks up into capillaries and all these capillaries reunite to form the renal veins. The two pelvic veins unite to form the anterior abdominal vein which is attached to the body wall internally along the mid-ventral line. The anterior abdominal vein runs forward and enters the liver where it breaks up into a number of capillaries. Blood from the stomach, intestine, pancreas and spleen is collected by the corresponding veins which unite to form a large hepatic portal vein which after giving off a branch to the anterior abdominal veins enters the liver and breaks up into capillaries. All these capillaries again unite to form the hepatic veins which open into the post-caval.

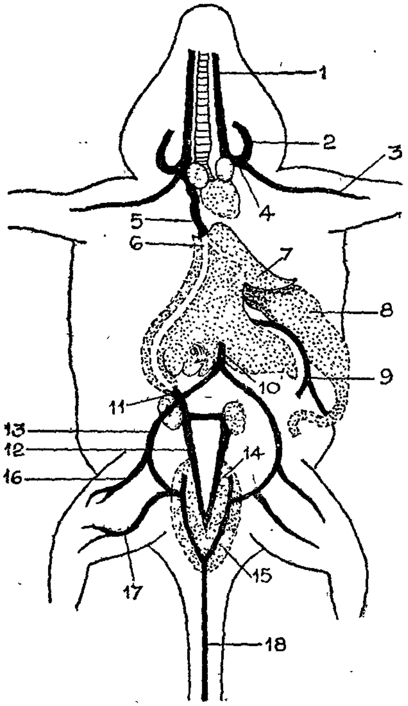

Fig. 112

Calotes—Venous System

1. External jugular 2. Internal jugular
3. Subclavian 4. Pre caval
5, 6, 11. Post caval 7. Hepatic 8. Liver
9. Hepatic portal 10. Anterior abdominal
12, 14. Efferent renal 13. Pelvic
15. Renal portal 16. Femoral
17. Sciatic 18. Caudal

Venous System in Lizard: The impure blood from the different parts of the body is collected by a pair of precaval veins and a post-caval vein. Each precaval vein is formed by the union of an external Jugular, an internal Jugular and a subclavian. These collect

the blood from the head and forelimbs respectively. The post caval vein starts from the kidneys. Actually it is formed by the two renal veins. The right renal vein is continued as the post caval and the left one joins it. The post caval vein passes through the liver where it receives a pair of hepatic veins and then it opens into the right auricle. The venous blood from the tail region is collected by a median caudal vein which divides at the base of the tail into two pelvic veins. Each pelvic vein runs across the ventral surface of the sorresponding kidney and gives off a short renal portal vein which breaks off into capillaries in the kidney. Hence the renal portal system is poorly developed. The two pelvic veins unite in front of the kidneys to form a short abdominal vein which enters into the liver and breaks off into capillaries. Each pelvic vein in its course receives the femoral and the sciatic veins from the hindlimb. The liver receives the hepatic portal vein from the wall of the stomach and the intestine. It directly carries the glucose to the liver where it stores it in the form of insoluble glycogen.

Venous System in Bird (Columba livia): The veins carry blood towards the heart. Impure blood from different parts of the body is collected by three large veins namely two precavals and a single post caval. These open independently into the right auricle. There is no sinus venosus in bird. Each precaval vein is formed by the union of three veins known as the jugular vein, the brachial vein and the pectoral vein which collect blood from the head wing and flight muscles respectively. The post caval vein is formed by the union of two iliac veins. Each iliac vein is joined by the femoral vein from the leg, the efferent renal vein from the kindey and the renal portal vein from the posterior region. It receives three hepatic veins before opening into the right auricle. The blood from the tail is collected by the caudal vein. It splits into the right and the left renal portal veins which enter the kidneys. Before entering kidney each renal portal vein is joined by the internal iliac vein from the pelvic region. As it passes through the kidney it also receives the sciatic and the femoral vein. It emerges from the kidney as the iliac vein. The renal portal veins do not break up into capillaries within kidneys. So the renal portal circulation is not quite well developed. There is a distinct coccygeo mesenteric vein which joins at the place where the caudal vein divides into two renal portal veins. Epigastric vein collects

blood from the mesentery and joins one of the hepatic veins. This vein corresponds to the abdominal vein of frog.

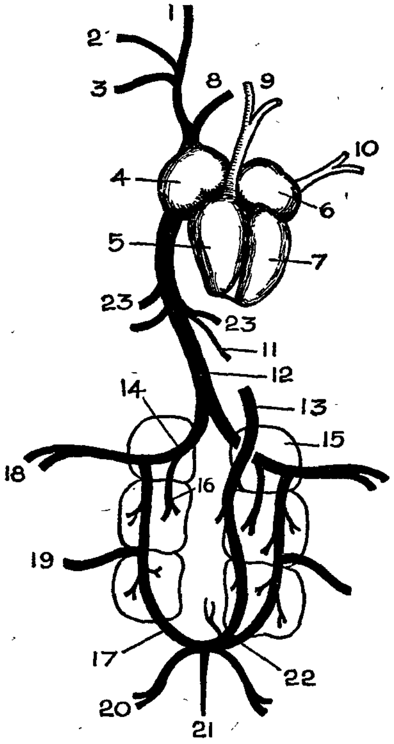

Fig. 113 Columba livia—Venous System

1. Jugular vein 2. Brachial vein 3. Pectoral vein
4. Right auricle 5. Right ventricle 6. Left auricle
7. Left ventricle 8. Precaval vein 9. Pulmonary artery
10. Pulmonary vein 11. Epigastiric vein 12. Post caval vein
13. Cocygeo mesenteric vein 14. Iliac vein 15. Kidney
16. Renal vein 17. Renal portal vein 18. Femoral vein
19. Sciatic vein 20. Internal iliac vein 21. Caudal vein
22. Renal portal vein 23. Hepatic vein.

Venous System in Rat: The impure blood from the different regions of the body is collected by three large veins namely the two precaval veins and a single post caval vein. Each pre caval vein is formed by the union of the internal ugular vein and the subclavian vein. The internal jugular vein

drains the blood from the occipital region. The subclavian vein is formed by the union of external jugular vein and the axillary vein. The external jugular vein collects blood from the face and the neck. The brachial vein collects blood from the fore arm. On the left side an azygos vein opens into the precaval vein.

The post caval vein is formed by the iliac veins. Each iliac vein in-turn is formed by the union of external iliac and the femoral vein. The caudal vein collects blood from the tail and drains it into the post caval. The post caval proceeds forward in the trunk and in its course receives the following veins (i) ilio lumbar (ii) lumbar from the lumbar region (iii) paired gonadial veins from the gonad.. The right gonadial vein drains the blood into the post caval while the left gonadial vein drains the blood into the renal vein (iv) Adrenals join the renal veins. (v) the renals from the kidney. The post caval passes through the liver where it receives the paired hepatic veins and pierces through the diaphragm and enters into the right auricle. The liver receives the hepatic portal vein from the stomach and the intestine thus forming the hepatic portal system.

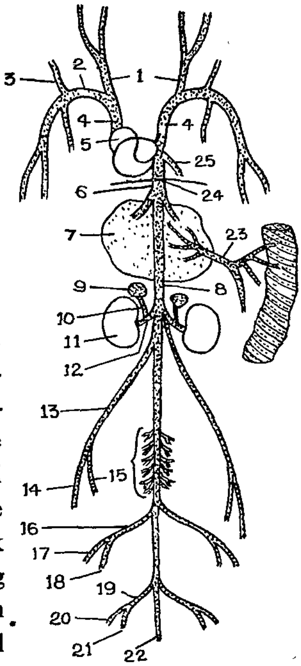

Fig. 114 Rat—Venous System

1. Internal jugular
2. Sub-clavian 3. Externa jugular 4. Superior venacava 5. Right auricle
6. Post caval vein 7. Liver
8. Inferior Vena cava
9. Supra renal body
10. Supra renal vein
11. Kidney 12. Renal vein
13. Spermatic vein
14. Testicular vein
15. Epididymal vein
16. Ilio lumbar 17. Iliac
18. Lumbar 19. Common iliac 20. External iliac
21. Femoral 22. Caudal vein 23. Hepatic portal vein 24. Diaphragm
25. Azygos vein

CHAPTER XIV

Nervous System

A. BRAIN

MUGEIL

The brain is safely lodged within the bony neurocranium. The brain is composed of nerve cells and is covered by a single membrane called the primitive meninx. The brain can be divided into three regions namely an anterior fore brain (prosencephalon), a middle mid brain (mesencephalon) and a posterior hind brain (Rhombencephalon). The fore brain is composed of paired olfactory lobes, paired cerebral hemispheres

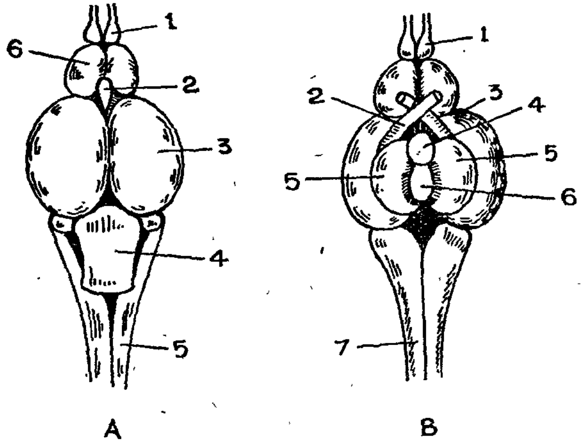

Fig. 115 Mugeil—Brain
A. Dorsal View
1. Olfactory lobe 2. Pineal body 3. Optic lobe 4. Cerebellum 5. Medulla oblongata 6. Cerebral hemisphere
B. Ventral View
1. Olfactory lobe 2. Optic nerve 3. Optic lobe 4. Infundibulum 5. Saccus vasculosus. 6. Pituitary body 7. Medulla oblongata.

and an unpaired diencephalon. The mid brain is composed of a pair of optic lobes. The hind brain is composed of cerebellum

and medulla oblongata. The olfactory lobes are small in size. Each olfactory lobe gives rise to an olfactory nerve. Olfactory lobes are concerned with the sense of smell. Each olfactory lobe encloses a much reduced olfactory ventricle. The cerebral hemispheres are slightly enlarged. They enclose the lateral ventricles. They are concerned with the initiation of voluntary actions. The optic lobes are very much enlarged. This is due to keen sense of sight. Each optic lobe encloses the optocoel or optic ventricle. They are concerned with the sense of sight. Each optic lobe on the ventral side gives rise to an optic nerve. The right and left optic nerves cross each other without forming a chiasma. The cerebellum is shieldlike. The medulla oblongata passes through the foramen magnum as the spinal cord into the vertebral column. On the ventral side of the brain and behind the optic chiasma is the infundibulum. Attached to the infundibulum is the pituitary. It is partly nervous and partly endocrine in its functions. On either side of the pituitary body is a pair of lobes termed as Lobi inferiores (Lobus inferioris-singular) whose function is not known. A small lobe is attached to the pituitary body termed as the saccus vasculosus. It is concerned with the detection of the pressure of the water. The brain presents a typical bilaterally symmetrical arrangement. It is concerned with the control and coordination of the various vital activities of the animal.

FROG

The brain is lodged in the bony brain case or neurocranium. It is covered by two membranes namely an outer duramater and an inner membrane called secondary meninx. The brain is divisible into three regions namely the forebrain, midbrain and the hindbrain. The forebrain consists of paired olfactory lobes in front, the paired cerebral hemispheres in the middle and the unpaired diencephalon behind. The olfactory lobes are fused externally in the median line and encloses cavities called the olfactory ventricles. They are concerned with the sense of smell. The greater part of the forebrain consists of two relatively large elongated cylindrical bodies called the cerebral hemispheres. The cerebral hemispheres are concerned with the conduction of nerve impulses from the olfactory lobes to the diencephalon and the initiation of voluntary

movements. Each cerebral hemisphere encloses a cavity called the lateral ventricle which communicates anteriorly with olfactory ventricle and behind with the cavity of the diencephalon or the third ventricle through an opening, the foramen of Monro. The roof of the third ventricle is a non-nervous and highly vascularised membrane called the anterior choroid plexus. The diencephalon bears dorsally a small finger like process the pineal body or epiphysis. On the ventral side of the diencephalon is a bilobed structure the infundibulum to which is attached the pituitary gland or hypophysis. Anterior to the infundibulum the two optic nerves cross each other and their fibres intermingle to form an 'X' shaped structure called the optic chiasma.

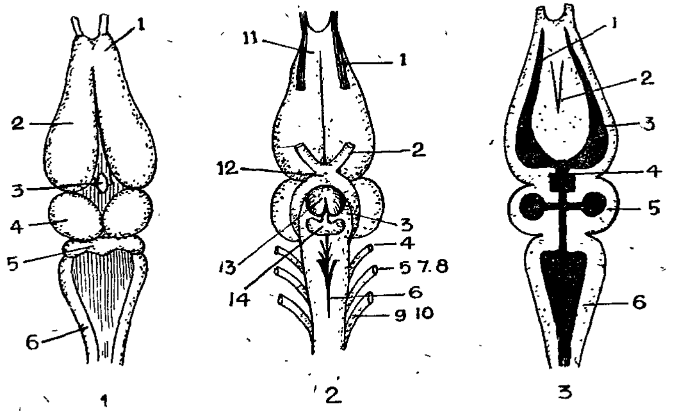

Fig. 116 Frog—Brain

1. Dorsal View 2. Ventral View 3. Section

1. 1. Olfactroy lobe 2. Cerebral hemisphere 3. Pineal body 4. Optic lobe 5. Cerebellum 6. Medulla oblongata.

2. 1 to 10. Cramial nerves 11. Olfactory lobe 12. Optic Chiasma 13. Infundibulum 14. Pituitary body.

3. 1. Olfactory ventricle 2. Cerebral hemispheres 3. Cerebral Ventricle 4. 3rd Ventricle 5. Optic Ventricle 6. 4th Ventricle.

The midbrain consists of a pair of large oval optic lobes. The posterior ends of the optic lobes are in contact with each other while the anterior ends diverge so as to enclose a portion of diencephalon. Each optic lobe encloses a cavity called the optic ventricle or optocoel. The two optic ventricles communicate with a central narrow passage the iter or aqueductus Sylvius

which connects the third and fourth ventricles. The floor of the optic lobes is formed of thick nerve matter the crura cerebri. The optic lobes are concerned with the sense of sight.

The hind brain consists of the cerebellum in front and the medulla oblongata behind. The cerebellum forms a narrow transverse band of nerve matter just behind the optic lobes and it controls equilibrium and muscular activities. The medulla oblongata is the posterior-most part of the brain and it is continued as the spinal cord. It is triangular in outline and encloses the fourth ventricle. Its roof is covered by a highly vascular membrane, the posterior choroid plexus. The medulla oblongata is a very important part of the brain in the frog and this can be demonstrated by the fact that even after the removal of other parts of the brain the frog can still leap, swim, capture and swallow food, breathe normally and live for a shortwhile if the medulla is retained. From this we can infer that medulla oblongata controls most of the body functions.

LIZARD

The brain is lodged inside the bony cranium. The brain is elongated in the antero posterior direction. The brain is covered by two membranes of connective tissue termed the meninges. The inner membrane is termed as the secondary meninx while the outer membrane is the duramater. The brain is divided into three regions namely the forebrain, the mid brain and the hind brain. The divisions of the brain are similar to that of the frog. The olfactory lobes are small in size and are connected to the cerebral hemispheres by means of long and slender olfactory peduncles. This is a characteristic feature of the brain of lizards. The cerebral hemispheres are much larger in size than in the amphibians. This is due to the enlargement of the corpora striata. The roof of the cerebral hemispheres is distinguished as the pallium while the floor and the sides are distingushied as the corpora striata. Diencephalon is a narrow portion of the brain overlapped by the cerebral hemispheres and the optic lobes. Its dorsal wall is termed as the epithalamus, the ventral wall as the hypothalamus and the lateral walls as the thalamus. The roof of the diencephalon is composed of a thin highly vascularised membrane

termed the anterior choroid plexus. The roof gives rise to an evagination termed the pineal body. The mid brain is composed of a pair of optic lobes which are oval in shape. It receives the nerve fibres from the optic nerves. Since the optic lobes are two in number it is also described as corpora bigemina. The hind brain is composed of cerebellum and medulla oblongata. The cerebellum occurs as a semicircular flap in lizards. Medulla oblongata is the posteior-most part of the brain. It

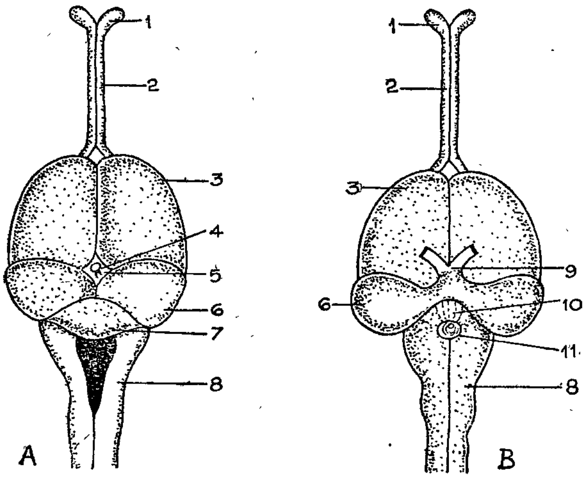

Fig. 117 · Calotes—Brain

A. Dorsal View B. Ventral View

1. Olfactory lobe 2. Olfactory peduncle 3. Cerebral hemis phere 4. Pineal body 5. Diencephalon 6. Optic lobe 7. Cerebellum 8. Medulla oblongata 9. Optic chiasma 10. Infundibulum 11. Pituitary body.

passes through the foramen magnum as the spinal cord into the vertebral column. The roof of the medulla oblongata is thin and non-nervous. It is termed as the posterior choroid plexus. On the ventral side of the diencephalon as in the frog the optic chiasma, infundibulum and the pituitary body are present. The cavities of the brain and the functions are similar to that of the frog.

BIRD

The brain is lodged in a thin walled cranium. Loss of ossification helps to reduce the weight of the skull. It

is an adaptation to flight. The sutures between the bones have largely disappeared so that the skull functions as a compact unit, and thus prevents the pressure of the air acting on the articulating facets of the bones. The brain is covered by two membranes namely an outer duramater and an inner secondary meninx. As in the other vertebrates the brain is divided into three regions namely the forebrain, mid brain and the hind brain. The fore brain is composed of a pair of olfactory

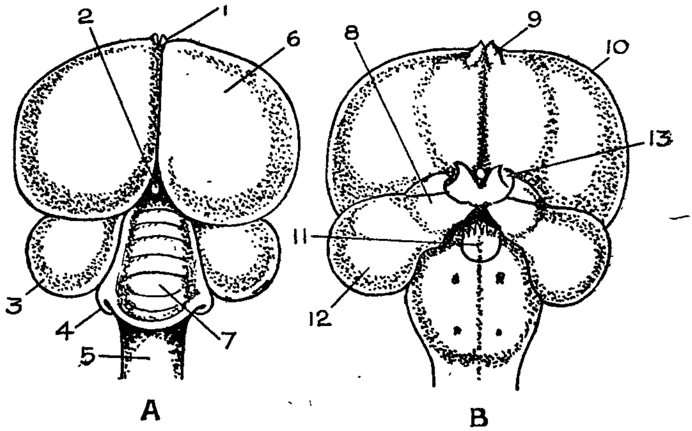

Fig. 118 Bird—Brain

A. Dorsal View B. Ventral View

1. Olfactory lobe 2. Pineal body 3. Optic lobe 4. Medulla oblongata 5. Spinal cord 6. Cerebral hemisphere 7. Cerebellum 8. Optic chiasma 9. Olfactory lobe 10. Cerebral hemisphere 11. Pituitary body 12. Optic lobe 13. Optic nerve

lobes, paired cerebral hemispheres and an unpaired diencephalon. The olfactory lobes are poorly developed. They occur as small elliptical bodies on the antero ventral surfaces of the cerebral hemispheres. The degeneration of the olfactory lobes is due to the poor development of the sense of smell. The cerebral hemispheres are very large in size. The pallium is small and thin as in reptiles. The enlargement of cerebral hemispheres is due to the complex corpora striata. Diencephalon is a narrow portion of the brain overlapped by the cerebral hemispheres and the optic lobes. Its dorsal wall is termed the epithalamus, the ventral wall as the hypothalamus and the lateral walls as the thalamus. The roof of the diencephalon is

composed of a thin highly vascularised membrane termed the anterior choroid plexus. The roof gives rise to an evagination termed the pineal body. The optic lobes occupy a lateral position due to the enlarged cerebral hemispheres and the cerebellum. The optic lobes are well developed and this is correlated with the keen sense of sight characteristic of birds. The cerebellum is very much enlarged consisting of a median vermis and two lateral lobes termed the flocculi. The medulla oblongata is the posterior–most part of the brain. It passes through the foramen magnum into the vertebral column as the spinal cord. The roof of the medulla which is membranous and richly supplied with blood vessels is termed as the posterior choroid plexus. On the ventral side of the brain in the region of the diencephalon the following structures are present. An X shaped optic chiasma formed by the crossing of the optic nerves, an infundibulum and a pituitary body. The cavities of the brain and the functions of the parts of the brain are similar to that of frog and lizard.

RAT

The brain of rat is lodged inside the bony skull or the neurocranium. The brain is covered by three membranes namely an outer duramater, a middle arachnoid membrane

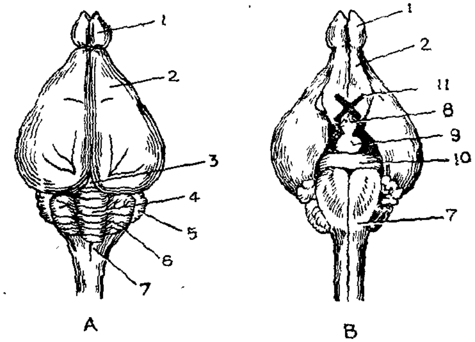

Fig. 119 Rat—Brain

A. Dorsal view B. Ventral view

1. Olfactory lobe 2. Cerebral hemisphere 3. Diencephalon
4 Vermis of cerebellum 5. Lateral lobe of cerebellum
6. Flocculus of cerebellum 7. Medulla oblongata
8. Infundibulum 9. Pituitary body 10. Pons varoli
11. Optic chiasma

and an inner highly vascularised piamater. In between the duramater and the arachnoid membrane is a space termed as the sub dural space. Similarly there is a space between the arachnoid membrane and the piamater, termed as the subarachnoid space. These spaces are filled with a fluid the cerebro spinal fluid. The membranes and the cerebro spinal fluid are protective in function. The brain of rat and in general of the other mammals is very highly specialised. It is made up of large number of nerve cells. The brain is divisible into three regions namely the forebrain, the midbrain and the hindbrain. The forebrain includes the olfactory lobes, cerebral hemispheres and the diencephalon. The midbrain includes the optic lobes, while the hindbrain includes the cerebellum and medulla oblongata. The olfactory lobes are comparatively large in size and solid in nature. They are present as two elliptical bodies from the anteroventral sides of the cerebral hemispheres. The cerebral hemispheres are large in size, and they occupy the greater part of the skull cavity. The two halves of the cerebral hemispheres are connected by a thin nerve sheet termed the corpus callosum. This is characteristic of mammalian brain.

The surface of the cerebrum is smooth in the rats, while in the other mammals the surface has numerous folds separated by distinct grooves. In the other mammals each half of the cerebral hemisphere can be divided into a frontal lobe in front, a parietal above, a temporal laterally, and an occipital at the posterior end. The diencephalon is hidden by the very much enlarged cerebral hemispheres. The diencephalon gives rise to a finger shaped out growth termed, the pineal body. The optic lobes are four in number. This condition is termed as copora quadrigemina. The cerebellum is equally highly specialised. It consists of a median lobe called vermis and it has two lateral lobes. Each lateral lobe is surrounded by a highly folded structure termed as the flocculus. The medulla oblongata is the posterior-most part of the brain. It passes through the foramen magnum, as the spinal cord into the vertebral column. On the ventral side of the mid brain as in the other vertebrates there are the optic chiasma, infundibulum and the pituitary body. Infundibulum is concerned with the temparature regulation of the body. Pituitary body produces the hormones, which controls the growth, meta-

bolism, development of skeleton and secondary sexual characters. On the ventral side of the cerebellum there is a transverse band of nerve matter termed as the pons varolii. This is characteristic of mammals.

B. SPINAL CORD

MUGEIL

The spinal cord develops from the posterior narrow part of the neural tube of the embryo. It lies in the neural canal of the vertebral column. It appears as a whitish tubular structure and it has an uniform diameter through out. It extends from the medulla oblongata to the end of the tail. It has a dorsal groove termed as the dorsal fissure, and a deep ventral fissure on the ventral side. The spinal cord has a central cavity termed as the cerebro spinal canal. It is lined by the ciliated epithelium and it is filled with the cerebro spinal fluid. The spinal cord is formed of an outer white matter and an inner grey matter. The white matter is covered by a thin membrane, primitive meninx, which is continuous with the cover ing of the brain. Spinal cord conducts sensory and motor impulses to and from the brain. It is also the seat of spinal reflexes. The mugeil has a number of spinal nerves. All of them have a similar origin and distribution. Each spinal nerve arises from the grey matter of the spinal cord by two roots namely a dorsal and a ventral root. The dorsal root forms the ganglion while the ganglion is absent in the ventral root. The dorsal root is composed of sensory fibres while the ventral root is composed of motor fibres. Hence the spinal nerve is a mixed nerve. Each spinal nerve divides into two branches namely dorsal ramus and ventral ramus.

FROG

Spinal cord in frog is a long whitish tubular structure present in the neural canal of the vertebral column. Anteriorly it joins the medulla oblongata of the brain. It is enlarged in the regions of the fore and the hind limbs. These are termed as the brachial and sciatic enlargements. The swellings are due

to the accumulations of large number of nerve cells. At the posterior end it narrows down to form the filum terminale. It

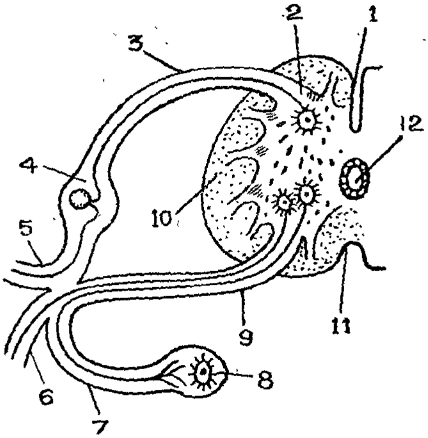

Fig. 124 Frog—Cross Section of Spinal Cord
1. Dorsal fissure 2. Grey matter
3. Dorsal root 4. Ganglion 5. Sensory nerve 6 Motor nerve 7. Ramus communicans 8. Sympathetic ganglion
9. Ventral root 10. White matter
11. Ventral fissure 12. Cerebro-spinal canal.

is flattened dorsoventrally. In other details it resembles the mugeil. It is covered over by two membranes, namely the duramater and the secondary meninx which is continuous with that of the brain. There are ten pairs of spinal nerves. The structure of the spinal nerves resembles that of the mugeil. In the spinal nerves there is a third branch, ramus communicans, and it joins the sympathetic nervous system.

LIZARD

The structure, histology and functions are same as that of frog.

PIGEON

The spinal cord and spinal nerves of pigeon resemble that of other vertebrates.

RAT

In the rat spinal nerves are classified into five groups. They are cervical in the region of neck, thoracic in the region of chest, lumbar in the region of abdomen, sacral in the hip region and coccygeal in the tail region. In the other details they follow the general vertebrate plan.